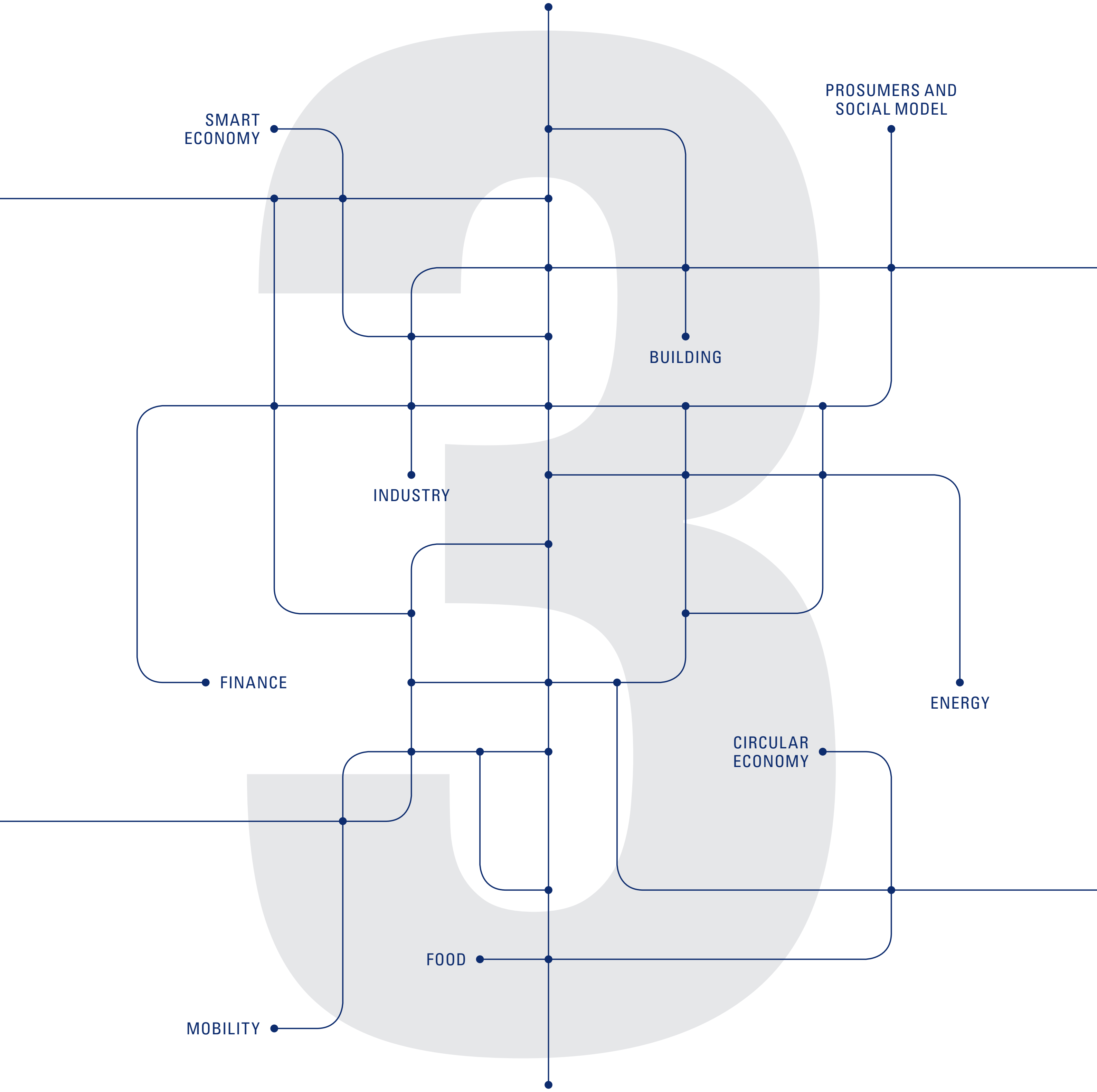
THE TIR CONSULTING GROUP LLC

THE 3RD INDUSTRIAL REVOLUTION STRATEGY STUDY



FOR THE GRAND DUCHY OF LUXEMBOURG

FINAL TIR STRATEGY STUDY • 14 NOVEMBER, 2016

The following Third Industrial Revolution Strategy Study contains the combined and integrated narrative and proposals of both the Grand Duchy of Luxembourg Working Group and TIR Consulting Group LLC

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PREFACE

The Grand Duchy of Luxembourg and TIR Consulting Group LLC have engaged in a deep collaborative initiative over the past twelve months, designed to transform the country into the first nation-state of the smart green Third Industrial Revolution era. The year-long project has culminated in a 475 page Third Industrial Revolution Strategy Study to help guide the Grand Duchy of Luxembourg into the next stage of its journey.

The process itself has established a new milestone in the governance of economic and social development. More than 300 socio-economic actors from government, the business community, academia, and civil society actively participated in the proceedings and in the preparation of the final Strategy Study and accompanying proposals. The government of the Grand Duchy of Luxembourg took on a new role as a facilitator of the process, replacing traditional top-down governance with a peer approach, engaging a broad representative swath of the Luxembourger community in jointly planning the Third Industrial Revolution Strategy Study. The final Third Industrial Revolution Strategy Study for the Grand Duchy of Luxembourg encompasses the combined input of the 300 stakeholders and TIR Consulting Group LLC's global team of experts.

The Third Industrial Revolution Strategy Study breaks additional ground by taking a cross-disciplinary approach to the future development of the Grand Duchy of Luxembourg, combining social, cultural, and environmental narratives and economic theory and business practices, with the goal of reconceiving economic development within a larger frame of "quality of life." While the early takeoff stage of the digital Third Industrial Revolution focused almost exclusively on new technologies, products, and services – the Silicon Valley model –, the Grand Duchy of Luxembourg has introduced the next level of engagement by concentrating equally on how the new Third Industrial Revolution infrastructure fosters an emerging global interconnectivity and accompanying planetary stewardship of the Earth's ecosystems – the Biosphere Valley model. In the Biosphere Era, Luxembourg and every other political jurisdiction becomes responsible for its 19 kilometers of the biosphere stretching from the stratosphere to the sea, which makes up the life force of the planet and constitutes the indivisible community to which we are all beholden and whose well-being determines our own quality of life. Biosphere stewardship becomes the essential mission of each region and locality in reducing ecological footprint and addressing climate change in the coming era.

The Third Industrial Revolution narrative proposed in this Strategy Study introduces a sophisticated and nuanced new approach to economic development based on establishing digital ecosystems that mirror the dynamics of natural ecosystems, with the goal of establishing a seamless symbiotic relationship between the circular flows of nature and the economic activities of the Luxembourger society. With this in mind, the Strategy Study continually hones in on critical ecosystem features including self-organization, mutualism, co-evolution, diversity, emergence, resiliency, and adaptation in modelling Luxembourg's new digital ecosystems and accompanying business practices and regulatory regime.

Luxembourg has now developed the vision, the narrative, and the game plan to usher in a smart green digital society, paving the way for the nationwide deployment of a Third Industrial Revolution transition.

The publication and deployment of the Third Industrial Revolution Strategy Study positions the Grand Duchy of Luxembourg as a flagship nation in the European Union build out and scale up of a smart digital society. As a major financial center of Europe, Luxembourg can play an important role in marshalling the financial resources and preparing the EU regulatory framework for the scaling of a Third Industrial Revolution infrastructure across the 28 Member States and adjoining partnership regions to advance the European Dream of a borderless digital infrastructure and integrated single market.

Jeremy Rifkin, President, TIR Consulting Group LLC

THE THIRD INDUSTRIAL REVOLUTION: THE DIGITAL INTERNET OF THINGS (IOT) PLATFORM AND THE PARADIGM SHIFT TO A SMART LUXEMBOURG

The global economy is slowing, productivity is waning in every region of the world, and unemployment remains stubbornly high in every country. Economists are predicting 30 more years of low productivity and slow growth. And now, after two Industrial Revolutions in the 19th and 20th Centuries, we can begin to assess the impact of this economic period in human history. Arguably, 50% of the human race today is far better off than our ancestors were before the onset of the industrial era. It is also fair to say that 40% of the human race, that is still making two dollars per day or less, is not appreciably better off than its ancestors were before the Industrial Revolution. At the same time, economic inequality between the rich and the poor is at the highest point in human history. Today, the combined wealth of the 62 richest human beings in the world equals the accumulative wealth of half of the human beings currently living on Earth – 3.5 billion people.[1]

This dire economic reality is now compounded by the rapid acceleration of climate change brought on by the increasing emissions of global warming gases during the First and Second Industrial Revolutions. James Hansen, former head of the NASA Goddard Institute for Space Studies and the chief climatologist for the U.S. government, forecasts a 6°C rise in the Earth's temperature between now and the turn of the century—and with it, the end of human civilization as we've come to know it. The only hope, according to Hansen, is to reduce the current concentration of carbon in the atmosphere from 385 ppm to 350 ppm or less—something no government is currently proposing.[2]

What makes these dramatic spikes in the Earth's temperature so terrifying is that the increase in heat radically shifts the planet's hydrological cycle. We are a watery planet. The Earth's diverse ecosystems have evolved over geological time in direct relationship to precipitation patterns. Each rise in temperature of 1°C results in a 7% increase in the moisture-holding capacity of the atmosphere. This causes a radical change in the way water is distributed, with more intense precipitation but a reduction in duration and frequency. The consequences are

[1] See: http://www.oxfam.org.uk/media-centre/press-releases/2016/01/62-people-own-same-as-half-world-says-oxfam-inequality-report-davos-world-economic-forum
[2] See: http://www.giss.nasa.gov/research/briefs/hansen_13/

already being felt in eco-systems around the world. We are experiencing more bitter winter snows, more dramatic spring storms and floods, more prolonged summer droughts, more wildfires, more intense hurricanes (category 3, 4, and 5), a melting of the ice caps on the great mountain ranges, and a rise in sea levels.[3]

The Earth's ecosystems cannot readjust to a disruptive change in the planet's water cycle in such a brief moment in time and are under increasing stress, with some on the verge of collapse. The destabilization of ecosystem dynamics around the world has now pushed the biosphere into the sixth extinction event of the past 450 million years of life on Earth. In each of the five previous extinctions, Earth's climate reached a critical tipping point, throwing the ecosystems into a positive feedback loop, leading to a quick wipe-out of the planet's biodiversity. On average, it took upward of 10 million years to recover the lost biodiversity. Biologists tell us that we could see the extinction of half the Earth's species by the end of the current century, resulting in a barren new era that could last for millions of years.

Now, however, a new economic paradigm is emerging that is going to radically change the way we organize economic life on the planet and dramatically reduce global warming emissions to address climate change. The European Union is embarking on a bold new course to create a high-tech 21st Century smart green digital economy, making Europe potentially the most productive commercial space in the world and the most ecologically sustainable society on Earth. The plan is called Smart Europe. The EU vision of a green digital economy is the cornerstone of the emerging Third Industrial Revolution.

To grasp the enormity of the economic change taking place, we need to understand the technological forces that have given rise to new economic systems throughout history. Every great economic paradigm requires three elements, each of which interacts with the other to enable the system to operate as a whole: new communication technologies to more efficiently manage economic activity; new sources of energy to more efficiently power economic activity; and new modes of transportation to more efficiently move economic activity.

In the 19th Century, steam-powered printing and the telegraph, abundant coal, and locomotives on national rail systems gave rise to the First Industrial Revolution. In the 20th Century, centralized electricity, the telephone, radio and television, cheap oil, and internal combustion vehicles on national road systems converged to create an infrastructure for the Second Industrial Revolution.

Today, the European Union is laying the groundwork for the Third Industrial Revolution. The plan calls for a digitally connected smart Europe. The Third Industrial Revolution involves much

[3] Kevin E. Trenberth, "Changes in Precipitation with Climate Change," *Climate Research* 47 (March 2011):123

more than providing universal broadband, free Wi-Fi, and a flow of Big Data. The digital economy will revolutionize every commercial sector, disrupt the workings of virtually every industry, bring with it unprecedented new economic opportunities, put millions of people back to work, democratize economic life, and create a more sustainable low-carbon society to mitigate climate change. Equally important, the new economic narrative is being accompanied by a new biosphere consciousness, as the human race begins to perceive the Earth as its indivisible community. We are each beginning to take on our responsibilities as stewards of the planetary ecosystems which sustain all of life.

The digitalized Communication Internet is converging with a digitalized Renewable Energy Internet, and a digitalized automated Transportation and Logistics Internet, to create a super-Internet to manage, power, and move economic activity. This super Internet rides atop an infrastructure called the Internet of Things (IoT). In the Internet of Things era, sensors and actuators will be embedded into every device and appliance, allowing them to communicate with each other and Internet users, providing up to the moment data on the managing, powering, and moving of economic activity in a smart Digital Europe. By 2030, it is estimated there will be more than 100 trillion sensors connecting the human and natural environment in a global distributed intelligent network. For the first time in history, the entire human race can collaborate directly with one another, democratizing economic life.

The digitalization of communication, energy, and transportation also raises risks and challenges, not the least of which are guaranteeing network neutrality, preventing the creation of new corporate monopolies, protecting personal privacy, ensuring data security, and thwarting cyber-crime and cyber-terrorism. The European Commission has already begun to address these issues by establishing the broad principle that “privacy, data protection, and information security are complimentary requirements for Internet of Things services.” These challenges will be addressed in the development and implementation of the TIR Strategy Study.

In this expanded digital economy, private enterprises connected to the Internet of Things will use Big Data and analytics to develop algorithms that speed aggregate efficiency, increase productivity, dramatically reduce ecological footprint, and lower the marginal cost of producing and distributing goods and services, making Luxembourg businesses more competitive in an emerging post-carbon global marketplace (marginal cost is the cost of producing an additional unit of a good or service, after fixed costs have been absorbed). The marginal cost of some goods and services in a Digital Europe will even approach zero, allowing millions of *prosumers*, connected to the Internet of Things, to produce and exchange things with one another, for nearly free, in the growing Sharing Economy.

AGGREGATE EFFICIENCIES AND PRODUCTIVITY

The transformation to an Internet of Thing infrastructure and a Third Industrial Revolution paradigm is forcing a wholesale rethinking of economic theory and practice. The unleashing of extreme productivity wrought by the digitalization of communication, energy, and transportation is leading to a reassessment of the very nature of productivity and a new understanding of ecological sustainability. Conventional economists fail to recognize that the laws of thermodynamics govern all economic activity. The first and second laws of thermodynamics state that "the total energy content of the universe is constant and the total entropy is continually increasing." The first law, the conservation law, posits that energy can neither be created nor destroyed—that the amount of energy in the universe has remained the same since the beginning of time and will be until the end of time. While the energy remains fixed, it is continually changing form, but only in one direction, from available to unavailable. This is where the second law of thermodynamics comes into play. According to the second law, energy always flows from hot to cold, concentrated to dispersed, and ordered to disordered. For example, if a chunk of coal is burned, the sum total of the energy remains constant, but is dispersed into the atmosphere in the form of carbon dioxide, sulphur dioxide, and other gases. While no energy is lost, the dispersed energy is no longer capable of performing useful work. Physicists refer to the no-longer-useable energy as entropy.

All economic activity comes from harnessing available energy in nature—in material, liquid, or gaseous form—and converting it into goods and services. At every step in the extraction, production, storage, and distribution process, energy is used to transform nature's resources into finished goods and services. Whatever energy is embedded in the product or service is at the expense of energy used and lost—the entropic bill—in moving the economic activity along the value chain. Eventually, the goods we produce are consumed, discarded, and recycled back into nature, again, with an increase in entropy. Engineers and chemists point out that in regard to economic activity there is never a net energy gain but always a loss in available energy in the process of converting nature's resources into economic value. The only question is: when does the bill come due?

The entropic bill for the First and Second Industrial Revolutions has arrived. The accumulation in carbon dioxide emissions in the atmosphere from burning massive amounts of carbon energy has given rise to climate change, the wholesale destruction of the Earth's biosphere, and the sixth extinction event in the history of our planet, throwing the existing economic model into question. The field of economics, by and large, has yet to confront the fact that economic activity is conditioned by the laws of thermodynamics.

Until very recently, economists were content to measure productivity by two factors: more capital invested in better performing machines and improved labor performance. But when Robert Solow—who won the Nobel Prize in economics in 1987 for his growth theory—tracked the Industrial Age, he found that machine capital and labor performance only accounted for approximately 12.5 percent of all of the economic growth, raising the question of what was responsible for the other 87.5 percent. This mystery led economist Moses Abramovitz, former president of the American Economic Association, to admit what other economists were afraid to acknowledge—that the other 87.5 percent is a "measure of our ignorance."[4]

Over the past 25 years, a number of analysts, including physicist Reiner Kümmel of the University of Würzburg, Germany, and economist Robert Ayres at INSEAD business school in Fontainebleau, France, have gone back and retraced the economic growth of the industrial period using a three-factor analysis of machine capital, labor performance, and thermodynamic efficiency of energy use. They found that it is "the increasing thermodynamic efficiency with which energy and raw materials are converted into useful work" that accounts for most of the rest of the gains in productivity and growth in industrial economies. In other words, "energy" is the missing factor.

A deeper look into the First and Second Industrial Revolutions reveals that the leaps in productivity and growth were made possible by the communication/energy/transportation matrix and accompanying infrastructure that comprised the general-purpose technology platform that firms connected to. For example, Henry Ford could not have enjoyed the dramatic advances in efficiency and productivity brought on by electrical power tools on the factory floor without an electricity grid. Nor could businesses reap the efficiencies and productivity gains of large, vertically integrated operations without the telegraph and, later, the telephone providing them with instant communication, both upstream to suppliers and downstream to distributors, as well as instant access to chains of command in their internal and external operations. Nor could businesses significantly reduce their logistics costs without a fully built-out road system across national markets. Likewise, the electricity grid, telecommunications networks, and cars and trucks running on a national road system were all powered by fossil fuel energy, which required a vertically integrated energy infrastructure to move the resource from the wellhead to the end users.

The general-purpose technology infrastructure of the Second Industrial Revolution provided the productive potential for a dramatic increase in growth in the 20th Century. Between 1900 and 1929, the United States built out an incipient Second Industrial Revolution infrastructure—the electricity grid, telecommunications network, road system, oil and gas pipelines, water and

[4] See: http://www.nber.org/chapters/c5650.pdf

sewer systems, and public school systems. The Depression and World War II slowed the effort, but after the war the laying down of the interstate highway system and the completion of a nationwide electricity grid and telecommunications network provided a mature, fully integrated infrastructure. The Second Industrial Revolution infrastructure advanced productivity across every industry, from automobile production to suburban commercial and residential building developments along the interstate highway exits.

During the period from 1900 to 1980 in the United States, aggregate energy efficiency—the ratio of potential to useful physical work that can be extracted from materials—steadily rose along with the development of the nation's infrastructure, from 2.48 percent to 12.3 percent. The aggregate energy efficiency leveled off in the 1990s at around 14 percent with the completion of the Second Industrial Revolution infrastructure.[5] Despite a significant increase in efficiency, which gave the United States extraordinary productivity and growth, nearly 86 percent of the energy we used in the Second Industrial Revolution was wasted during transmission.

Even if we were to upgrade the Second Industrial Revolution infrastructure, there will be only a limited effect on aggregate efficiency, productivity, and growth. Fossil fuel energies have matured. And the technologies designed and engineered to run on these energies, like the internal-combustion engine and the centralized electricity grid, have exhausted their productivity, with little potential left to exploit.

Needless to say, 100 percent thermodynamic efficiency is impossible. New studies, however, including one conducted by our global consulting group, show that with the shift to a Third Industrial Revolution infrastructure, it is conceivable to increase aggregate energy efficiency to 60 percent or more over the next 40 years, amounting to a dramatic increase in productivity beyond what the economy experienced in the 20th Century.

A 2015 McKinsey report suggests that the build out and scale up of an Internet of Things infrastructure will have a 'value potential' of between $3.9 trillion to $11.1 trillion per year by 2025.[6] A General Electric study published in November 2012 concludes that the efficiency gains and productivity advances induced by a smart industrial Internet could resound across virtually every economic sector by 2025, impacting "approximately one half of the global economy."[7] A

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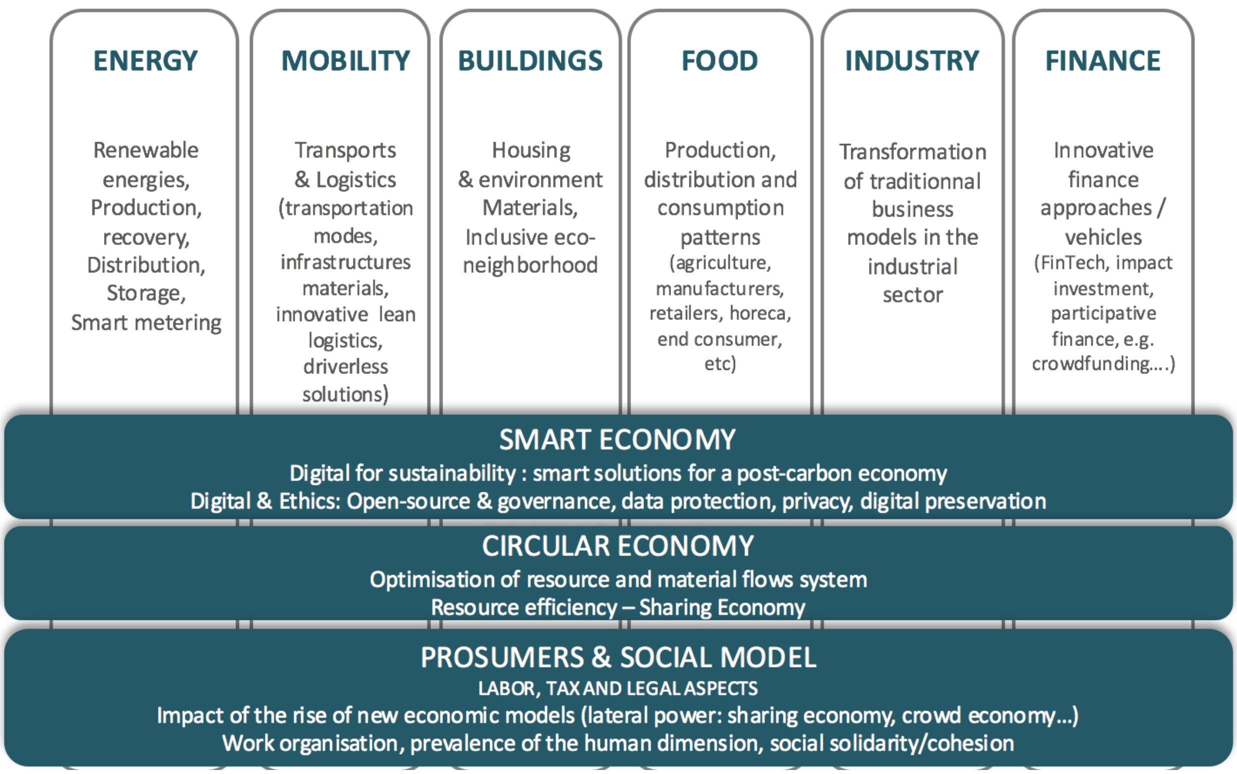
[5] John A. "Skip" Laitner, Steven Nadel, R. Neal Elliott, Harvey Sachs, and A Siddiq Khan, "The Long-Term Energy Efficiency Potential: What the Evidence Suggests," American Council for an Energy-Efficient Economy, January 2012, http://www.garrisoninstitute.org/downloads/ecology /cmb/Laitner_Long-Term_E_E_Potential.pdf, 2

[6] See: http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world

[7] See: https://www.ge.com/docs/chapters/Industrial_Internet.pdf

2016 AT Kearney study says that "over the next 10 years, the market for IoT solutions will be worth € 80 billion, and the potential value for the EU28 economy could reach € 1 trillion." The report goes on to say that the increase in productivity alone could exceed € 430 billion in the EU. However, AT Kearney is quick to add that the increased capabilities brought on by the digitalization of the infrastructure will "increase exponentially when connected objects are coordinated."[8]

The build out and scale up of the Third Industrial Revolution Internet of Things platform will enable businesses in Luxembourg to dramatically increase aggregate efficiencies across their value chains, increase productivity, and reduce marginal costs and ecological footprint, making the nation a leader in the shift to the new economic paradigm and an ecological society.



[8] See: https://www.atkearney.com/documents/10192/7125406/The+Internet+of+Things-A+New+Path+to+European+Prosperity.pdf/e5ad6a65-84e5-4c92-b468-200fa4e0b7bc

ENERGY

OVERVIEW

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The bulk of the energy we use to heat and cool our homes and run our appliances, power our businesses, drive our vehicles, and operate every part of the global economy will soon be generated at near zero marginal cost and be nearly free in the coming decades. That is already the case for several million early adopters in the EU who have transformed their homes and businesses into micro-power plants to harvest renewable energy on-site. In Sweden, already over 50% of the gross final energy consumption was generated from renewable sources in 2013.[9] Looking at electricity only, Austria and Sweden are leading the pack with close to 70% of their gross electricity production being generated from renewable sources, predominantly hydro power. Hydro power is the still largest source of renewable energy (370TWh as of 2013) but its share is declining due to the strong increase in generated solar (85 TWh in 2013, projected to increase to 121[10]-462[11] TWh in 2020) and on- and offshore wind (234TWh in 2013, projected to increase to 442-487 TWh in 2020[12]).

Currently, 32% of the electricity powering Germany comes from solar, wind and other renewable energies, accounting for approximately 15% of the total final energy consumption. By 2030, a minimum of 50% of the electricity powering Germany will be generated by renewable energies.[13]

In contrast, smaller, more densely populated countries like Belgium and the Netherlands are generating less than 10% of their total final energy use from renewable sources. Luxemburg's projected strong population growth and the fact that it is landlocked intensifies the challenge to meet EU 2020 and COP21 targets.

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[9] The State of Renewable Energies in Europe, Edition 2014, 14th EurObserv'ÉR Report
[10] Renewable energy progress report, European Commission
[11] Set for 2020. Solar Photovoltaic Electricity: A mainstream power source in Europe by 2020, European Photovaltaic Industry Association
[12] Wind energy scenarios for 2020, European Wind Energy Association, July 2014
[13] See: http://www.sueddeutsche.de/wirtschaft/gruener-strom-sommer-sonne-sorgen-1.2638800

In 2013, 74% of the energy produced in Luxembourg was generated by renewable energy sources (RES). However, since 97% of the energy consumed is imported, the share of RES on gross inland energy consumption is only 3.6%. Since petroleum, which accounts for 65% of total final consumption, is heavily consumed by transit traffic and cross-border commuters, the statistics show a more realistic picture without the transport sector. The share of RES on final energy consumption for electricity, heat and fuel for national transport (this does not include fuel tourism and fuel for cross-border commuters), is about 6.1%. The share of RES without renewables consumed in the transport sector (biofuels) amounts to 5.6% (excluding national transport) and to 6.1% (including national transport).[14]

In 2013 the final energy consumption without transport amounts to 19.2 TWh per year, composed of 6.8 TWh electricity and 12.4 TWh heat and cold, assumed that the conversion of gas and other energy carriers into heat is on the average 80%. With a "technical RES potential" of 14.4 TWh electricity and 20.7 TWh heat generated in the country, Luxembourg is theoretically able to generate about 250% of today's electricity and heat demand by its own RES. Photovoltaic has the highest potential with 7.9 TWh, followed by wind power with 5.7 TWh, Biogas and bio liquids in CHP plants with 0.6 TWh, and small hydro power with 0.1 TWh per year. In heat generation, solar thermal demonstrates the highest potential with 14.6 TWh, followed by solid biomass with 4.0 TWh, heat pumps with 1.5 TWh, and biogas and bio liquids in CHP plants with 0.6 TWh per year.[15] [16] Taking into account that the technical RES potential within the country is significantly higher than the expected energy demand in 2050, 100% of the energy demand could be generated by RES in the country.

The quickening pace of renewable energy deployment is due, in large part, to the plunging cost of solar and wind energy harvesting technologies. The reduction in fixed costs of solar and wind technologies have been on exponential curves for more than 20 years. In 1977, the cost of generating a single watt of solar electricity was 76 dollars, and by 2017 the cost is projected to be 55 cents/Watt.[17] After the fixed costs for the installation of solar and wind are paid back—often as little as five to eight years—the marginal cost of the harvested energy is nearly free. Unlike fossil fuels and uranium for nuclear power, in which the commodity itself always costs something, the sun and the wind are free. In some regions of Europe and America, solar and wind energy is already as cheap, or cheaper, than fossil fuel or nuclear generated energy.

[14] All data in the paragraph calculated by Fraunhofer ISE using data from: EU Commission, DG ENER, Unit A4: Energy Statistics, Energy datasheets: EU-28 countries, Luxembourg (values of 2013).
[15] *Ibid.*
[16] Aktualisierung der Potenzialanalyse für Erneuerbare Energien, Fraunhofer ISI, IREES, 2015
[17] See: http://www.nwclimate.org/news/solar-panel-efficiency-from-solarcity/

The impact on society of near zero marginal cost solar and wind energy is all the more pronounced when we consider the enormous potential of these energy sources. If we could grab hold of one-tenth of one percent of the sun's energy that reaches Earth, it would give us six times the energy we now use across the global economy. Like solar radiation, wind is ubiquitous and blows everywhere in the world—although its strength and frequency varies. A Stanford University study on global wind capacity concluded that if 20 percent of the world's available wind was harvested, it would generate seven times more electricity than we currently use to run the entire global economy.[18]

The Energy Internet is comprised of five foundational pillars, all of which have to be phased-in simultaneously in Luxembourg for the system to operate efficiently. First, buildings and other infrastructure will need to be refurbished and retrofitted to make them more energy efficient so that a high share of electricity, heat, and cold generated by renewable energy technologies can be installed. The renewable energy generated can be used in the building or delivered back to the electricity or heating grid. Reducing the energy needs of buildings allows traditional oil and gas based heating systems to be replaced by newer technologies like heat pumps. This will allow the share of renewables for space heating and cooling to increase massively. New buildings will need to meet the strictest standards for energy efficiency, by designing them as net positive energy buildings. The need for newly constructed residential buildings in Luxembourg, resulting from its projected substantial population growth, provides a great opportunity to transition into positive power building stock.

Second, ambitious targets must be set to replace fossil fuels and imported nuclear power with renewable energy sources. This includes a marked increase of energy efficiency in electricity and heat generation, e.g. by using combined heat and power technologies (conventional plants run by biogas or methane, and fuel cells run by hydrogen). To achieve this goal, Luxembourg has introduced a feed-in tariff to encourage early adopters to transform buildings and property sites into micro-power generation facilities. The feed-in tariffs guarantee a premium price above market value for renewable energies generated locally and sent back to the electricity grid. Past experience in several other EU countries suggests that the introduction of feed in tariffs can dramatically reduce the fixed and marginal cost of harvesting renewable energy and be phased out over time as the new green energies approach parity with conventional fossil fuels and nuclear power. Ultimately a legal and regulatory framework for the energy system will need to emerge where subsidies and hidden costs for fossil fuels and nuclear power that are currently embedded in the system are made explicit, thus creating a level playing field.

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[18] Cristina L. Archer and Mark Z. Jacobson, "Evaluation of Global Wind Power," *Journal of Geophysical Research*, Vol. 110.

Third, storage technologies including batteries, hydrogen tanks (in combination with fuel cells), pumped hydro storage, large thermal stores, etc., will need to be embedded at local generation sites and across the energy system to manage both the daily and seasonal intermittency of green electricity, heat and cold and the reduction of peak loads.

Fourth, advanced metering infrastructures and other digital technologies like energy management systems will need to be installed in every building, transforming the energy grid into a fully digitized bidirectional system in order to manage multiple sources of energy flowing to the grid from local generators (smart grid implementation). This will enable passive consumers of energy in Luxembourg to become active prosumers of their own green energy, which they can then use off-grid to manage their facilities, store, or sell back to the Energy Internet. Luxembourg's smart grid efforts have been primarily focused on the technical aspects of the smart grid. A more complete smart energy system is needed that includes connected, distributed markets for trading energy at both a local and national scale. Such a system will need to provide a positive business case for all stakeholders and enable end-user propositions that resonate well with Luxembourg’s residents and businesses.

Fifth, industrial, commercial, and residential spaces will need to be equipped with charging stations to allow electric vehicles to secure power from the Energy Internet, as well as to sell power back to the electricity grid. Electric vehicles connected to the Energy Internet also provide a massive storage system that help reduce the load on the grid during peak demand by providing local power and storing (local) power at times of excess renewable energy generation. New business models for the energy value chain are needed that allow vehicle owners to be appropriately compensated for the storage and generation services they provide.

The phase-in and the integration of the above pillars transform the entire energy infrastructure and, especially the electricity grid of Luxembourg, from a centralized to a distributed energy system, and from fossil fuel and nuclear generation to renewable energy. In the new system, every business, neighborhood, and homeowner becomes the producer of electricity, sharing their surplus with others on a smart Energy Internet that is beginning to stretch across national and continental landmasses.

This massive shift has started to appear in Germany with the establishment of energy cooperatives. Most of these cooperatives were successful in securing low interest loans from banks to install solar, wind, and other renewable energies on-site. The banks were more than happy to provide the loans, assured that the funds will be paid back by the premium price the cooperatives will receive—via feed-in-tariffs—from selling the new green electricity back to the grid.

The rise of local energy cooperatives has forced electricity companies to rethink their business practices. A decade ago, four giant vertically integrated electricity generating companies—E.ON, RWE, EnBW, and Vattenfall—were producing much of the electricity powering Germany. Today, they are losing market share, since fossil fuel and nuclear generated electricity has been reduced to 68 percent. At the same time, the big four power companies are producing less than 7 percent of the new green electricity that's taking Germany into a Third Industrial Revolution. Peter Terium, CEO of RWE, the German-based energy company, acknowledges the massive shift taking place in Germany from centralized to distributed power, and says that the bigger power and utility companies "have to adjust to the fact that, in the longer term, earning capacity in conventional electricity generation will be markedly below what we've seen in recent years."[19] Companies like E.ON and RWE are spinning off their fossil-based activities into separate businesses in anticipation of the changing role of traditional power plants in the energy system.

In the future, in the fully liberalized European energy market, traditional energy suppliers will increasingly generate income by erecting and operating the Energy Internet and managing their customers' energy use by taking on additional roles as both Energy Service Company Providers (ESCO) and aggregators of energy services. Suppliers and grid operators alike will mine Big Data across each of their clients' value chains and use analytics to increase their aggregate energy efficiency and productivity, and reduce their marginal cost. Their clients, in turn, will share the efficiency and productivity gains back with the utilities in what are called "Performance Contracts." In short, energy companies will profit more from managing energy use more efficiently, and selling less rather than more electricity.

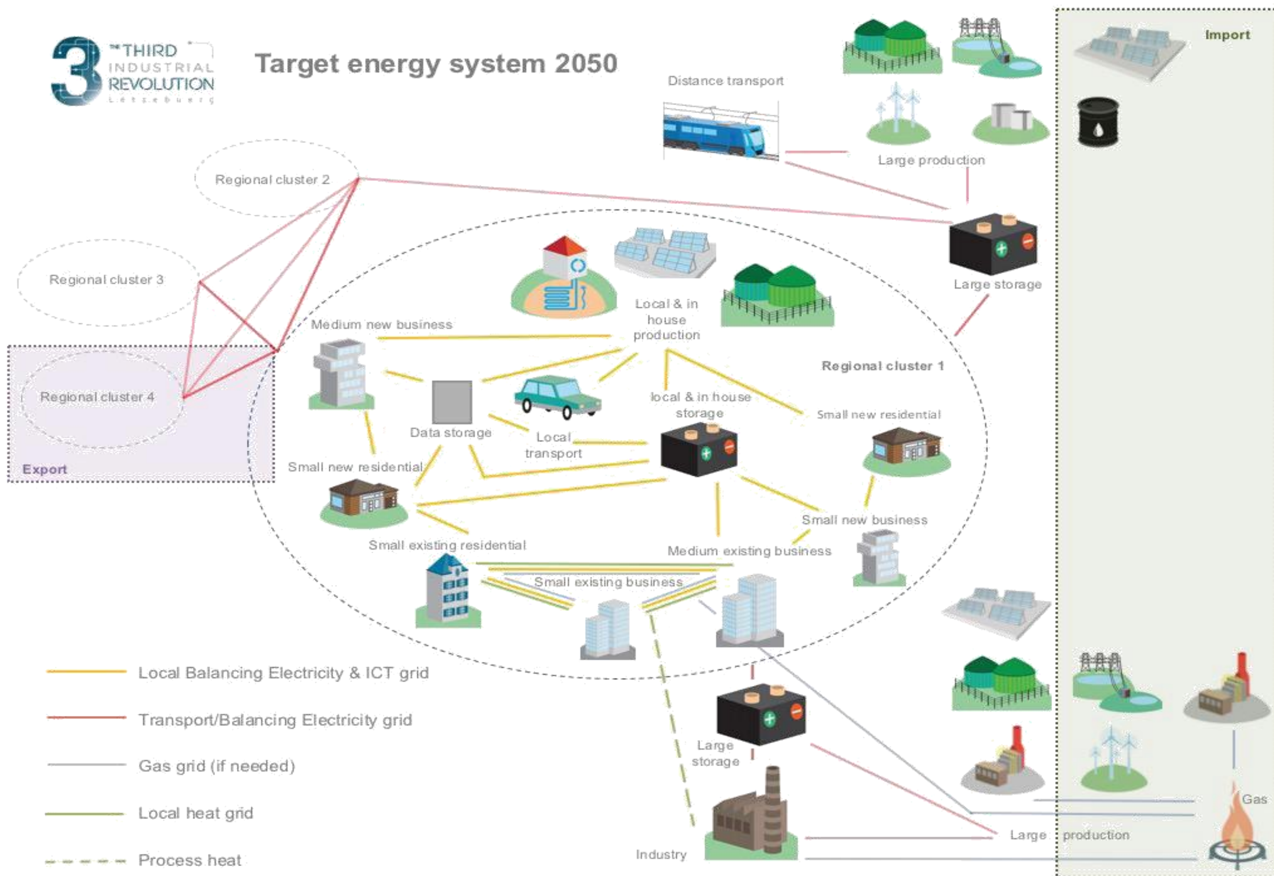
Luxembourg Vision "Energy System 2050"

The participants of the Luxembourg Energy Working Group have set forth a bold vision of a smarter energy future in Luxembourg described in eight transformational initiatives:

1. Significant reduction of energy consumption through increased energy efficiency.
2. The energy production in 2050 will be based almost exclusively on renewables.
3. Energy production and consumption will increasingly be distributed.
4. Local and/or regional energy clusters will become increasingly more important.
5. Centralized production and distribution of energy (in particular electricity) will remain at least a back-up component of the energy system.
6. Innovative ICT solutions will be the basis of a flexible demand side management and thus contribute to an increased flexibility of the energy market(s).
7. The mobility sector will essentially rely on electricity.
8. As a prosumer, the client will play a crucial role in the future energy system.

[19] See: http://www.reuters.com/article/us-utilities-threat-idUSBRE92709E20130308

In order to realize this vision, the chairs of the Energy Working Group, with the assistance of *myenergy*, describe a "Target Energy System 2050" vision for Luxembourg:



Schematic representation of the energy system 2050

The Target "Energy System 2050" is Composed of Five Critical Keystones:

Sources of Energy for the Target System 2050

- The energy future of Luxembourg will mainly be based on renewable energy sources and the mix should be free of nuclear and coal. In particular, solar, wind, biomass, and geothermal energy will play an important role. A small share of fossil fuel energy sources (like crude oil and natural gas) could still be part of the energy system in 2050 for back-up and transition reasons – and because the country will most likely still need to import a certain percentage of its energy.

Autonomous Regional Energy Clusters

- The energy system 2050 will be predominantly organized by autonomous regional energy clusters. Within the clusters, smart local microgrids allow the exchange of data and energy among the different prosumers, aiming at an efficient intra-cluster demand side management. Small decentralized production units based on renewable energy sources provide electricity to the prosumer. Electricity links to other regional clusters are needed in case the local balancing cannot accommodate the 'domestic' energy demand/supply. If available and economically sound, heat and/or cold exchange within a cluster (for instance based on waste heat from industry) can contribute to the diversification of the cluster portfolio. Thus, local heat and existing gas grids could remain, at least in part, to provide energy for existing buildings. Finally, the concept of autonomous clusters can also be understood independently from geographical proximity via the creation of Internet-based 'virtual' clusters.

ICT Infrastructure Crucial at all Levels of the "Target Energy System 2050"

- ICT infrastructure represents the backbone of the future energy system. Centralized, distributed, and decentralized data storage centers as well as data grid and metering infrastructure are the basis of intra- and inter-exchange of energy and data by the autonomous clusters.

Interconnection of the Regional Energy Clusters

- Transport and balancing electricity grids connect regional clusters with the industrial sector, large production units, energy storage facilities as well as other regional clusters.

Reliance on Imports

- The "Target Energy System 2050" implies a further reliance on energy import. In particular, gas and its infrastructure will remain an element of the energy system of the future: a) on a general level for the industrial sector (and maybe the distance transport sector) and b) possibly as energy storage (by converting surplus electricity produced from renewable energy sources into gas).

Finally, in order to quantify the transformation path towards the envisioned energy system 2050, the Working Group agreed on the following objectives for 2025, 2040 and 2050:

	2025	2040	2050
Renovation rate per year	3%	3%	3%
Energy demand reduction per capita (without petrol exports)	-20%	-35%	-50%
% of nationally produced renewable energy in relation to the total national consumption	15%	30%	50-100%*
Import	*The remaining share of the national consumption that cannot be covered by nationally produced renewable energy.*		

**100%: a) if economically sound, b) some members of the working group think that 100% should be targeted in order to be in line with the objectives of the COP21 agreement*

The working group agreed on the following interpretation of the enumerated objectives:

- Luxembourg should leverage the total energy efficiency potential that can be achieved through the renovation of the building stock.
- Luxembourg should optimize the generation of economically feasible renewable energy production potential in the country. This should cover a majority of its energy demand.
- Energy imports will continue to be necessary, but will decrease depending on the share of nationally produced renewable energy.
- The imported energy mix should also be predominantly renewable so that overall (locally produced + imported) energy consumption reaches at least 80% renewables.

Roadmap 2050:

Based on the "Target Energy System 2050," 24 key areas were chosen as the critical priorities for advancing the long term agenda:

1. "Promotion of RE through the adaptation of the legal framework and the establishment of simplified procedures"
2. "Promotion of RE, self-consumption and e-mobility through the adaptation of the funding programs and/or taxation schemes"

3. “Identification and promotion of new business models for energy services”
4. “Adaptation of market designs”
5. “First experimental distribution grid cluster(s)”
6. “Promotion and development of new technologies”
7. “Develop incentives and a regulatory and economic framework for the operation of electricity storage sites”
8. “Optimization of CO2 trading mechanism scheme”
9. “Adaption of grid (data and electricity, heat / cooling)”
10. “Heat recuperation in industrial, commercial and residential buildings”
11. “Centralized collection of data via smart meters”
12. “Regulation of self-consumption”
13. “Extension of Vianden: regulation, flexibility”
14. “Innovation in renovation”*
15. “Invest in waste to energy”*
16. “Define compulsory share of renewable energy”
17. “Automatic IoT system to provide “uniforme load”
18. “Develop geothermal energy”*
19. “Realization of Power-to-Gas infrastructure projects”
20. “Increase the number and size of clusters”
21. “Bonus/Malus regulations, implementation based on “Energiepass”
22. “Promote industrial demand side management”
23. “Optimize production portfolio in cluster”
24. “Develop e-mobility infrastructure”*

STATE OF PLAY AND LUXEMBOURG VISION

Introduction

This complementary report presents the combined views from a team of independent energy experts[20] from the Energy Pillar within the Third Industrial Revolution Strategy Study for Luxembourg. This report provides expert insights on the transition path toward a future energy system for Luxembourg. It incorporates the findings from the initial Luxembourg Energy Working Group (WG) workshops held between February and April 2016, as well as more recent results from the Executive Seminar held in Luxembourg on May 25-26, 2016 and a follow-up meeting held in Luxembourg on July 5, 2016.

Presented first is our view of the changing energy landscape affecting Luxembourg, Europe, and the rest of the world. In this section, we describe drivers such as the COP21 Paris Agreement and the various European Union energy targets and directives, as well as global trends in energy sector transformation and technology deployment. Next, we assess Luxembourg's 2050 Vision for Energy in the context of the current state of the country's energy demand, supply, networks, and markets. We then present our priority recommendations for enabling the energy transition in Luxembourg, building on several of the initial 10 measures proposed by the Energy Working Group. These recommendations are organized along the following three themes: market design and regulatory framework, new business models and financial schemes, and experimental distribution grid clusters. We end by summarizing our specific proposals for the TIR roadmap for Energy and Luxembourg's 2050 Vision for Energy.

A Changing Energy Landscape: Europe Energy Outlook 2050

Luxembourg is firmly embedded in Europe and its institutions. An analysis of Luxembourg's energy future can therefore not be made without understanding the key drivers changing Europe's energy landscape.

COP21[21]

The COP21 Paris Agreement is probably the most important international agreement influencing how we perceive, produce, and consume

[20] These experts include DNV GL, Fraunhofer, and Navigant.
[21] Paris Agreement, FCCC/CP/2015/L.9/Rev.1 (PDF). UNFCCC secretariat, December 2015.

energy. The COP21 conference culminated in a global agreement on the reduction of climate change. Important provisions include:

- Holding the increase in the global average temperature to well below 2° C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5° C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change
- Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas (GHG) emissions development, in a manner that does not threaten food production

The agreement will become legally binding once 55 parties that produce over 55% of the world's GHG emissions have ratified it. Within the Intended Nationally Determined Contributions (INDCs), individual countries will specify how they will contribute to the global goals.[22]

European Union Targets

The EU has three main sets of targets with respect to increasing the share of renewable energy, increasing energy efficiency, and reducing GHG emissions among its Member States:

1. **Renewable energy:** Achieve at least 20% of total energy needs by renewable energy by 2020 and ensure at least 10% of transportation fuels come from renewable sources by 2020[23]
2. **Energy efficiency:** Achieve 20% energy savings compared to projected 2020 energy use[24]
3. **GHG emissions reductions:** Achieve reductions in GHG emissions by 80%-95% by 2050[25]

Europe's Energy Roadmap 2050 explores pathways for the transition to a new energy system that meets these GHG emissions goals while simultaneously promoting competitiveness and security of supply.[26] In its analysis, the EU concludes that decarbonization is technically and economically feasible. A European approach is expected to result in lower energy costs and more secure energy supplies, compared to individual national schemes.

[22] Luxembourg's NDC is, understandably, not available yet, but will hopefully be inspired by the outcome of the TIR project.
[23] See http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm and links therein.
[24] See https://ec.europa.eu/energy/en/topics/energy-efficiency and links therein
[25] See http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52011DC0885&from=EN
[26] See https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf

Single Energy Market[27]

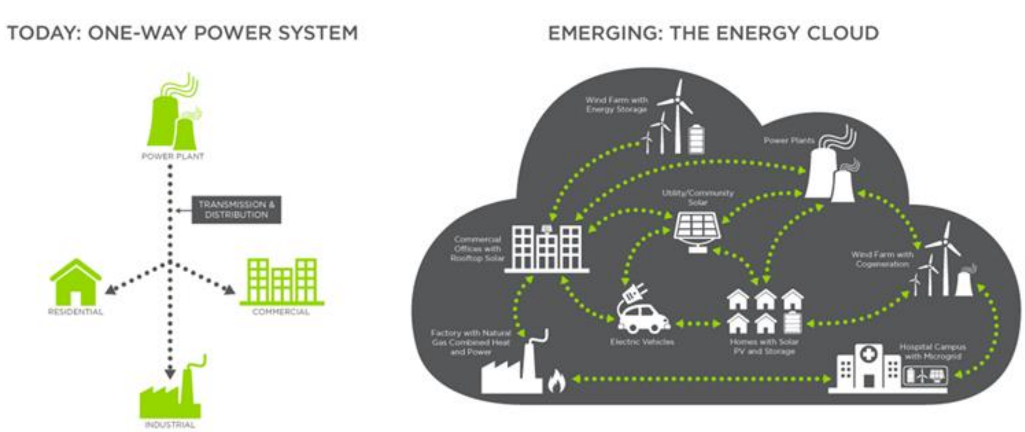
The European Commission is strongly focusing on the harmonization of energy markets in the EU, leading to a single internal market for energy. The free movement of goods, services, capital, and labor is a founding principle of the EU. To accomplish this principle for electricity, a single electricity market is imperative. A single electricity market is also fundamental for Europe to meet its low carbon targets and achieve economic optimization at a European scale.

With a single internal market, energy can be produced where it is cheapest and delivered to where it is needed. A more nationalistic approach, where countries individually manage their security of supply, is an economically inferior alternative that is not in line with European solidarity principles.

Energy Sector Transformation

The energy sector is transforming on a global scale, as well as within Europe. It is changing from a centralized, one-way, hub-and-spoke grid—based on large centralized generation assets like fossil fuels, hydro, or nuclear power plants—towards a more distributed grid, with an increased role for renewables and distributed energy resources (DER), as well as more sophisticated operating characteristics and controls. In the future, the power grid will be far more dynamic, responsive, and democratized than current infrastructure allows.

Figure 1: The Energy Cloud Landscape[28]



In this emerging Energy Cloud landscape – a concept that borrows from cloud computing – tremendous change is occurring within a range of technical, commercial, environmental, social,

[27] See https://ec.europa.eu/priorities/energy-union-and-climate/fully-integrated-internal-energy-market_en and links therein.

[28] See https://www.navigantresearch.com/research/the-energy-cloud

economic, and regulatory platforms. As with the IT cloud, a dynamic platform is emerging to enhance the efficient allocation of DER—including distributed generation (DG), energy storage systems, energy efficiency, demand response (DR), plug-in electric vehicle (EV) charging, and microgrids—across a broad customer base.

The energy sector is adapting to this evolving landscape through business model transformation and a general rethinking of traditional stakeholder engagement strategies. In addition, energy consumers and vendors alike are experiencing unprecedented opportunity to enhance and, in some cases, replace the status quo.

Six key trends underpin the energy sector's evolution to the Energy Cloud:

- Greater customer engagement and demand for more sustainable energy options
- Increasing number of policies and regulations aimed at reducing carbon emissions
- Shareholders seeking value through new ventures and mergers and acquisitions
- The regionalization of energy import and export of oil and natural gas, growing regionalization of power markets, and increasing interconnection over land and sea
- Mega industries emerging around growth opportunities such as smart cities, transportation, and building and home energy management
- Old infrastructure being replaced and geared toward an increasingly distributed and smarter power grid architecture

This architecture will enable a two-way power flow such that distinctions between distribution and transmission grids will blur. The acceleration in the sophistication and pervasiveness of remote monitoring and automation equipment, combined with robust data analytics, is already allowing more granular and real-time control over generation and consumption, even at the edges of the grid. This mix of hardware and software enables greater precision with respect to matching localized supply and demand with higher levels of frequency, all of which is required for cost-optimal functioning of the Energy Cloud architecture, as well as for capturing the resource efficiencies anticipated from the Third Industrial Revolution by 2050.

Global Technology Trends[29]

Technology innovations are largely driven by policy and regulation, climate change, sustainable use of resources, and the digitization of the energy system. Table 1 summarizes two global impact scenarios resulting from contrasting policy and regulatory approaches. Given the focus on COP21 and regional and country-specific environmental policy and regulatory mandates,

[29] See http://to2025.dnvgl.com/energy/

these scenarios are more likely to result in significant shifts in how we produce, distribute, and consume electric energy.

Table 1: Energy Sector in 2025

State of Global Energy Sector in 2025				
WEAK PUSH FROM POLICY AND REGULATIONS Transformation of the energy sector relies primarily on market-based incentives, allowing countries to tailor mechanisms to national needs and circumstances.	Demand for all fossil fuels continues to follow the growth trajectory of the gross world product.	**Demand for fossil fuels**	Coal demand peaks, oil demand declines, and natural gas demand shows moderate growth.	STRONG PUSH FROM POLICY AND REGULATIONS Governments predominantly use regulatory measures to force energy sector transformations, rather than rely on incentives.
	Lack of concerted action by OPEC drives oil price volatility.	**Oil price**	Policy mechanisms dampen oil price volatility.	
	Energy security is assured through trade agreements at national or regional level.	**Energy security**	International energy policy drives transition toward global, low carbon energy security.	
	No significant carbon price implemented across the energy sector.	**CO_2 pricing**	Carbon pricing implemented across the energy sector in most developed countries.	
	Global capacity is less than 1 TWh.	**Uptake of solar PV**	Global capacity is close to 3 TWh.	
	Global capacity is less than 1 TW. Limited growth in offshore wind.	**Uptake of wind**	Global capacity is more than 2 TW. Moderate growth in offshore wind.	
	Fewer than 10 large-scale projects without associated hydrocarbon production.	**Uptake of Carbon Capture & Storage (CCS)**	20-30 large-scale projects without associated hydrocarbon production.	
	50% growth to 2025.	**Uptake of biofuels**	Lignocellulosic biofuels become cost-competitive with fossil transportation fuels by 2025.	
	20% growth to 2025.	**Deployment of nuclear**	60% growth to 2025.	
	Less than 20 million EVs by 2025.	**Uptake of EVs**	More than 80 million EVs by 2025.	

Source: *Technology Outlook 2025, DNV GL AS, 2016*

Specific technological trends that can be identified are:

- **Wind turbines** are now manufactured in very large numbers and represent a mature technology. Still, significant developments continue. Turbine sizes for the offshore market are increasing, driven by the high cost of foundations and installation. Turbines rated up to 8 MW and with diameters greater than 170m are already installed, with designs reaching 12 MW and 200m.
- Further developments in wind **turbine technology** include light, flexible blades and aerodynamic control devices, as well as innovations in transmission systems, new sensors, and smart control systems.
- For **solar PV technologies**, materials such as graphene have the potential to increase efficiencies dramatically. Combining the expected market growth and the historical cost reduction, it is clear that by 2025 solar PV will be the cheapest form of electricity in many regions of the world, driving several changes in the power system.
- For **power converter technologies**, wide bandgap semiconductors are capable of higher switching frequencies (kHz) and blocking voltages (upward of tens to hundreds of kV), while providing for lower switching losses, better thermal conductivities, and the ability to withstand higher operating temperatures, increasing the reliability and efficiency of next-generation electric grids.
- **Microgrids** are localized power grids that operate in synchrony with, or independently from, the main grid. They are, by definition, a distribution network that incorporates a variety of possible distributed energy resources that can be optimized and aggregated into a single system that can balance loads and generation, with or without energy storage, and is capable of islanding whether connected or not connected to a traditional utility power grid. As such, they offer resilience against weather disasters, and both physical and cyber disruptions to the main power grid.
- Over the next decade, we expect a steep decline in **battery energy storage** prices and a correspondingly rapid increase in home energy storage solutions. This development, which is driven in part by the rapid rise of renewables in the energy mix, will pave the way for a growing number of electricity prosumers.
- Technological developments are starting to make **demand response management** (DRM) solutions possible that combine the benefits of both approaches, resulting in much more viable DRM options that create much-needed flexibility for variable wind and solar integration. By 2025, DRM will be an indispensable service to prosumers and, as such, will provide retailers and aggregators with a tool to differentiate their services in new ways.

Luxembourg 2050 Vision for Energy

Participants of the Luxembourg Energy Working Group have set forth a bold vision for a smarter energy future.[30] Underlying this vision is a number of contextual drivers that set Luxembourg apart from the rest of Europe, including:

- **Population growth.** Luxembourg's population is expected to almost double by 2050.[31] Ignoring finer demographic points, this translates to a doubling of the number of households and the number of household dwellings. This will create a need for new and renovated buildings, which in turn presents an excellent opportunity to create a more sustainable building stock by ensuring all newly erected buildings meet the Passive House[32] criteria, and all existing building stock is converted to Passive House standards over time.
- **Small, open economy.** The success of the Luxembourg economy depends, in large part, on open access to and from other EU countries. This access includes a free flow of people—i.e., about 45% of Luxembourg's total labor force today consists of cross-border workers from Belgium, France, and Germany.[33] Luxembourg's economy is also highly reliant on the finance sector, as well as its flourishing information and communications technology (ICT) sector.
- **Transportation sector.** A large part of Luxembourg's final energy consumption goes towards transportation, specifically the transport of goods by road, cross-border workers, and ancillary fuel tourism. In order to become fully sustainable, a deep decarbonization of the transportation sector is needed.

Energy Demand

In cooperation with Luxembourg's statistical agency, STATEC, TIR Consulting Group LLC has created a scenario for 2050 where overall energy demand is reduced by 44%. At the same time, however, the team believes a more ambitious target setting is desirable and feasible, and has worked with STATEC to create the Ambitious Energy Efficiency Scenario (AEE).

In this scenario, the total energy demand of Luxembourg is reduced from ~25 GWh to ~17 GWh in 2050, a reduction of 33%, while at the same time the population of the country nearly

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[30] TIR Pillar Energy – Note finale de restitution", TIR Luxembourg - Final Outcome Document - WG Energy.pdf
[31] Source Eurostat, see http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00002&plugin=1 for details.
[32] As of January 1 2017, all new residential construction in Luxembourg will need to meet the Passive House standard.
[33] Luxembourg in Figures, STATEC, 2015

doubles. This translates into per-habitant reductions of 63% in 2050, compared to 2016. This is indeed very ambitious. Note that this does not include fuel exportation.

In the AEE scenario, as detailed in Table 2, projected transportation savings comes from a reduced use of cars and a higher capacity utilization of public transportation. As there is nearly no potential for liquid biofuels, it is assumed that the whole transportation sector will be electrified (only passenger transport, no trucks are considered) and that public transport will have a share of one-third of the electricity demand.

Table 2: Final Energy Demand in 2015 and Projections for 2050[34]

(Reference 2050 Scenario and an AEE Scenario in Absolute and Specific Numbers)

Final Energy Demand in GWh	Unit	2015	STATEC 2050	AEE 2050
Population	*Inhabitants*	*571,884*	*1,026,876*	*1,026,876*
Electricity demand	GWh	5,895	6,924	5,821
Heat demand	GWh	13,322	13,015	8,372
Transport demand	GWh	6,202	5,606	2,784
Total	GWh	25,419	25,545	16,977
Reduction absolute			*0%*	*-33%*
Electricity demand per inh.	kWh/inh.	10,308	6,743	5,669
Heat demand per inh.	kWh/inh.	23,295	12,674	8,153
Transport demand per inh.	kWh/inh.	10,845	5,459	2,711
Total per inh.	kWh/inh.	44,448	24,876	16,533
Reduction per inhabitant			*-44%*	*-63%*

Energy Supply

To transform the energy system into a sustainable system by 2050,[35] Luxembourg will need to tap into its solar and wind power potential, augmented with additional sustainable sources such as biogas and biomass. This will aim to create the bulk of its energy supply and ensure that any remaining demand that is fulfilled through imports, also meets its sustainability criteria.

[34] During the drafting of the report, some updated demographic statistics and projections have been released. The changes have been relatively small and might explain small differences throughout the report (e.g. population growth).

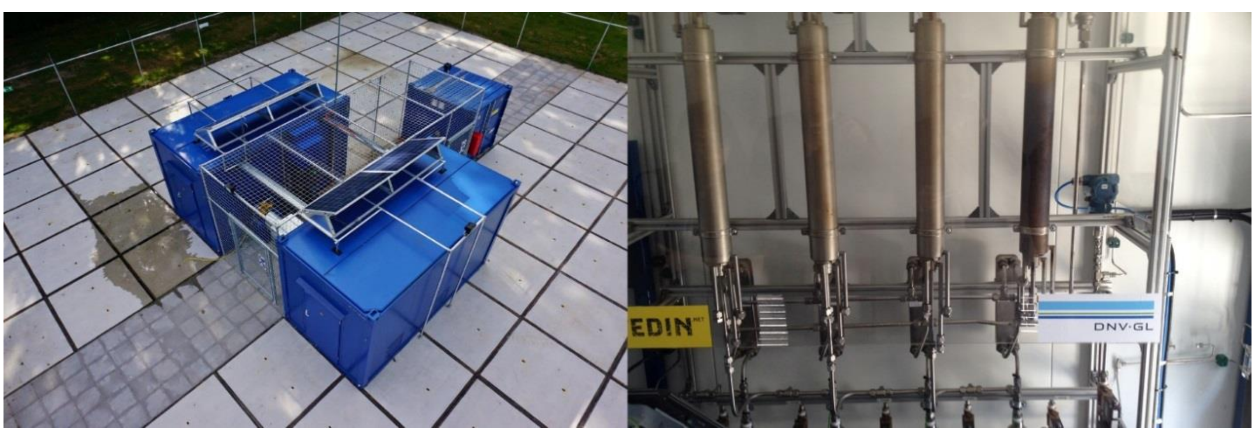
[35] According to the EU, Luxembourg does not seem to be on a path to meet the EU non-ETS GHG targets for 2020. To meet the goal for 2050 of a largely sustainable energy system, although technically feasible, requires more intense actions and interventions than currently foreseen.

An increasing adoption of solar PV and wind power can result in an undesirable situation where oversupply of sustainable energy at the European level during peak hours results in low, or even negative, wholesale energy prices. This phenomenon can also result in the switching off of renewable power generation capacity to reduce commercial losses and restore network stability. This would significantly affect the business case for investments in these assets and means that even the yearly energy balance for renewable energy will become negative again.

A solution to this scenario is through the application of energy storage and conversion technologies.

- **Energy Storage:** Using hot water tanks and/or battery systems for short-term energy storage. Such solutions are well-suited to store excess renewable energy for a few hours and, at best, a few days.
- **Conversion through power-to-gas:** Converting excess power generation into hydrogen or methane gas. The gas can be stored in underground storage facilities in large volumes and for long periods of time, to meet seasonal differences in the energy balance. Figure 2 shows photos of the relevant conversion technology.
- **Electric vehicles:** Connecting electric vehicles to the grid using a bidirectional charging pole infrastructure for EVs can form a virtual power plant and replace the need for a central power plant.

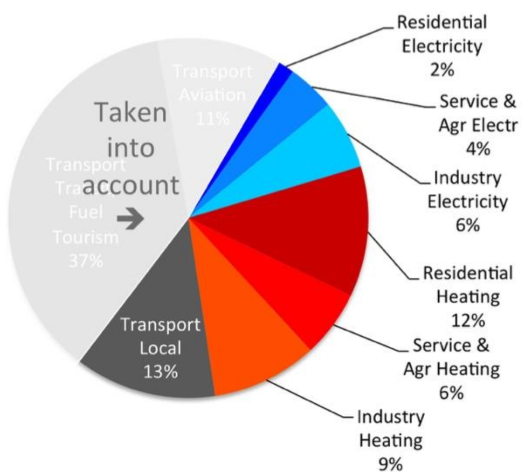
Figure 2: Small Power-to-Gas Unit with Close-Up of Methanization Reactors



Modeling Supply & Demand

Using the urban energy system modeling tool, KomMod, a cost-optimal structure of the target energy system in a temporal, highly-resolved simulation was calculated[36] in a manner that covers all energy sectors, including electricity, heating, cooling, and local transport energy, including their interdependencies.

Figure 3: Energy Demand Components Included for the Energy Supply Optimization



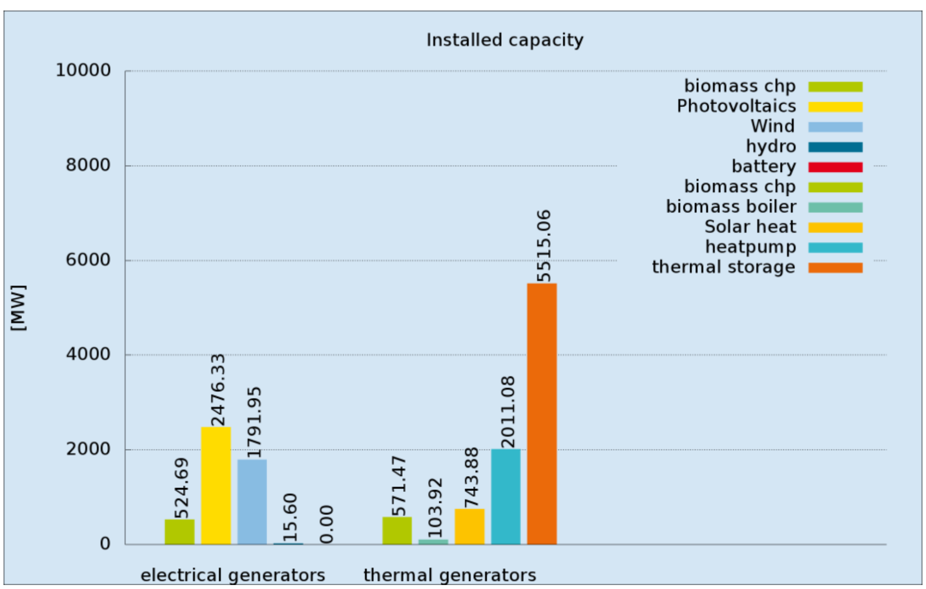
Sector distribution	Electr	Heat	Transp
Final energy demand	12%	27%	61%
Without fuel tourism, transit, aviation	**23%**	**52%**	**24%**

This modeling, which accounts for the energy demand components shown in Figure 3, shows that given Luxembourg's technical potential, it is feasible that the country could produce 100% of its renewable energy domestically. The Energy Working Group set a goal of producing a majority of its energy – between 50% and 100% - with domestically produced renewables. With this in mind, the TIR Consulting team ran three Ambitious Energy Efficiency (AEE) potential scenario models with 50%, 70% and 100% of the energy generated domestically by renewable energies. While the scenario modelling found that producing 100% of its energy domestically would be technically feasible, a scenario where only 70% is locally generated and 30% imported is far more cost-effective, as shown in Figures 4 and 5. However, producing 70% of Luxembourg's renewable energy needs domestically by 2050 may be a conservative figure. As

[36] Input to the Energy Sub-Report, 'Results of Modelling the Energy System of Luxembourg.' Gerhard Stryi-Hipp, Fraunhofer ISE, 27 July 2016.

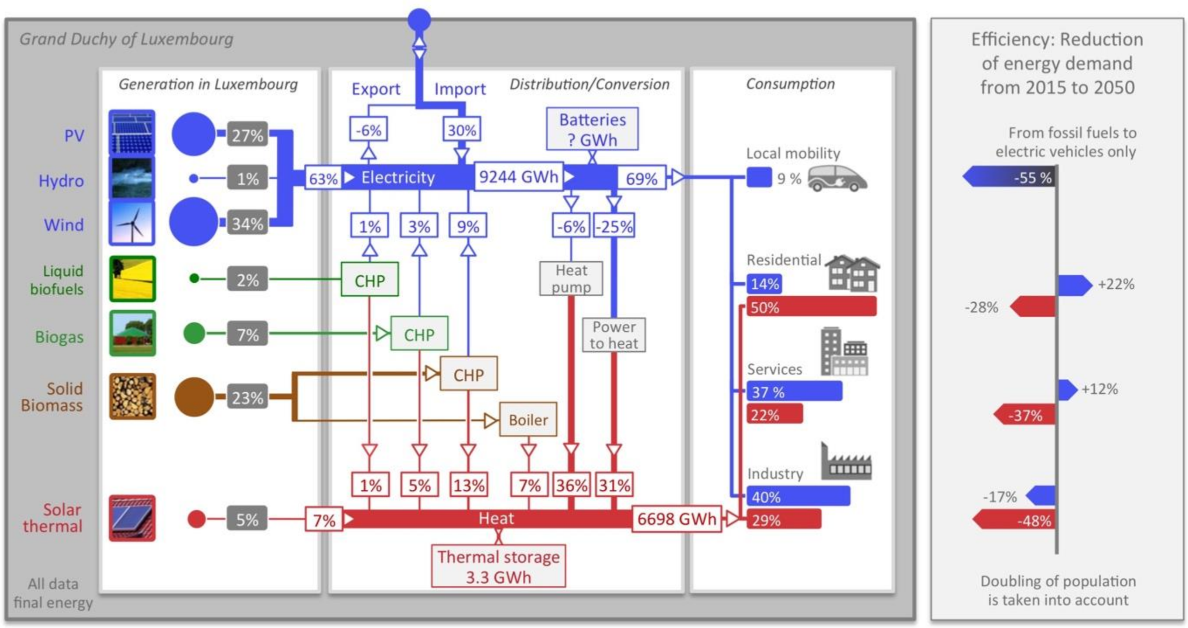
mentioned in other sections of the Third Industrial Revolution Strategy Study, the reduction in the fixed cost of solar and wind generation has been on an exponential curve for 20 years (for example, in 1977, the cost of generating a single watt of solar electricity was 76 dollars, and by 2017 the cost is projected to be 55 cents/Watt[37]). The fixed costs in generating renewable energy will continue to plunge on an exponential curve while the marginal costs remain near zero. Moreover, the fixed costs of renewable energy storage technologies are also declining and will be increasingly cost-effective in managing intermittent solar and wind energy over the course of the next 35 years. In addition, as the Third Industrial Revolution Internet of Things infrastructure continues to evolve and become increasingly interoperational, additional exponential curves will emerge, dramatically increasing aggregate efficiency and productivity, while dramatically reducing ecological footprint and accompanying external costs, making domestically produced solar and wind even more cost effective and attractive. For all of the above reasons, it is possible that Luxembourg will find it cost-effective to increase the domestic production of renewable energy beyond the 50% minimum benchmark set out in our energy modelling scenarios to 70% or more.

Figure 4: Installed Renewable Energy Capacity to Achieve 70% Electricity Self-Generation for the AEE Demand Scenario



[37] See: http://www.nwclimate.org/news/solar-panel-efficiency-from-solarcity/

Figure 5: Energy Flow Graph of the 70% Electricity Self-Generation Scenario for the AEE Demand Scenario



Remark: Battery capacity still to be defined, according the modelling results, batteries are not necessary to guarantee a secure supply in each hour of the year since import/export is not limited.

The energy grids are not part of this modeling, and the effects of DR have not been taken into account. KomMod assumes a greenfield situation in 2050, not taking into account existing assets. It also assumes excess solar energy can be sold on the international market during the day, and that energy can be bought and imported into Luxembourg during the evenings. However, this is a questionable assumption, since excess solar energy will be a fact of life for most European countries in the near future, limiting the ability to sell excess production and increasing the economic viability of battery energy storage.

This modeling, therefore, shows that it is possible to transform the energy system of Luxembourg, which is highly dependent on energy imports today, into a sustainable energy system in 2050, which is mainly supplied by renewable energy sources.

Energy Networks

The level of grid interconnection capacity in Luxembourg is already very high. Nevertheless, investments in interconnections would further improve the security of the country's energy supply, especially when considering the foreseen demographic and economic evolution.

Detailed planning of the required interconnection capacity needed in 2050 will be necessary, since the energy balance, as well as the peak load on the interconnectors, will change significantly as Luxembourg moves toward a more sustainable energy supply in 2050.

It is also important to consider the gas entry capacity which, due to the limited size of the country, depends heavily on individual consumers. Following the closure of the country's sole CCGT, the total demand has dramatically decreased. In contrast, the peak load on the power interconnectors with its neighboring countries will most likely increase.

On a local level, similar issues arise in the distribution power grid. The maximum installed capacity of ~12 MW for solar PV and 1.7 MW for heat pumps, plus additional load from plug-in EVs, will lead to an even higher localized peak load on the distribution grid. If supply and demand is properly matched, a significant amount of the solar PV peak load can be absorbed by the load of the heat pumps and EVs. This results in a limited increase in the local peak load on the distribution grid.

It will take detailed dynamic load flow calculations to estimate the expected peak loads, since the load will become strongly dependent on the location of the generation source over time, combined with the ability to locally absorb that power using DR or storage solutions. This is necessary for accurate planning of the needed capacity and to ensure the right level of investments and the timely extension of grid capacity. Otherwise, load shedding becomes inevitable, leading to dissatisfied customers and underperformance with respect to Luxembourg's sustainability goals.

Energy Markets

Luxembourg will continue to rely on the exchange of energy and flexibility through open European markets, but will have to significantly increase its share of nationally produced renewable energy. This also reduces security of (sustainable) supply risks, although this is not a primary driver for the country.

A market structure should be in place to support the connection of local demand and supply. The EPEX Spot exchange[38] could potentially provide the services to do so, but the current market structure most likely will not support an open infrastructure that is accessible for energy traders. EPEX SPOT is currently focused on large volumes of power trading and does not yet incorporate the locality of the production, nor does it provide access for small players like energy communities or prosumers.

[38] See https://www.epexspot.com/en/

The current power exchange markets do not yet offer services for flexibility trading, which becomes essential once the step towards a fully sustainable energy system is made and power production, to a large extent, is based on renewable power via wind and solar.

Flexibility is the ability of a power system to maintain continuous service in the face of rapid and large swings in supply or demand.[39] Flexibility will become a commodity in itself that is essential to match demand to the local supply of power. Specific flexibility products are necessary, as is the adjustment of market processes so that flexibility trading can be included.

In order to create widespread use of flexibility, a new market has to emerge at the national and European level. Aggregated flexibility will have value and can be sold to the network operator (to prevent congestion) or to parties that are trying to match energy demand to the supply from various sources, at the lowest possible cost.

Intermediaries (aggregators) will try to maximize the value of their customers' flexibility by trading it in the marketplace. This will take place under the condition that the future energy market is transparent, and provides a level playing field where every player has an equal role and opportunity to participate.

Resiliency in the Energy Internet

Maintaining resiliency of critical infrastructure, such as electric power networks, telecommunications systems, and buildings, becomes paramount when considering the various vulnerabilities arising from catastrophic climate change related weather events, as well as the potential impacts to human health, safety, security, and social well-being. While resiliency is frequently considered in the context of climate change and more frequent severe storm events, the TIR team focus also includes a view of resiliency in relation to cyber or physical attacks to these infrastructure systems (extreme weather events can be considered as conditions that differ substantially from the norm, and consequently might not have been taken into account when designing cities, power and telecommunications networks, supporting infrastructure, and new or retrofited buildings).

Buildings and other infrastructure (e.g., bridges, roadways) can be vulnerable to extreme weather events, due to their design (low resistance to storms) or location (e.g., in flood-prone areas). They can be damaged or rendered unfit for use by any changing climatic condition or extreme weather event, including extreme precipitation and floods, extreme low or high temperatures, heavy snowfalls, strong winds, and wildfires across areas experiencing severe

[39] Flexibility Options in Electricity Systems, Ecofys, 2014.

draught and dry conditions. Consequences of climate change for buildings and infrastructure will certainly differ from region to region, but there is some certainty that Luxembourg has such vulnerabilities.

Electric power infrastructure, in particular, can be exposed to a number of extreme weather events and some vital infrastructure components may be subsequently compromised, causing highly detrimental impacts to countries such as Luxembourg. Specifically, high-voltage transmission circuits and associated substations are often identified as critical assets, given long lead times for obtaining replacement power equipment (e.g., substation transformers can take up to 18 months to acquire), as well as the large population served by this infrastructure.

Figure 6 shows an overview of the largest global power outages through 2015. Here the year of occurrence (x-axis), duration (y-axis), and number of people impacted (relative size of the bubbles) are compared. It can be observed that the most common cause of these blackouts was "natural phenomena" (six times), while design and application error, communications failure, and operator errors were the second largest contributors. These kinds of power outages are usually caused by a combination of technical failures and human errors, where a fault or defect occurs at a critical moment and is then misinterpreted, after which an appropriate, but incorrect action is taken.

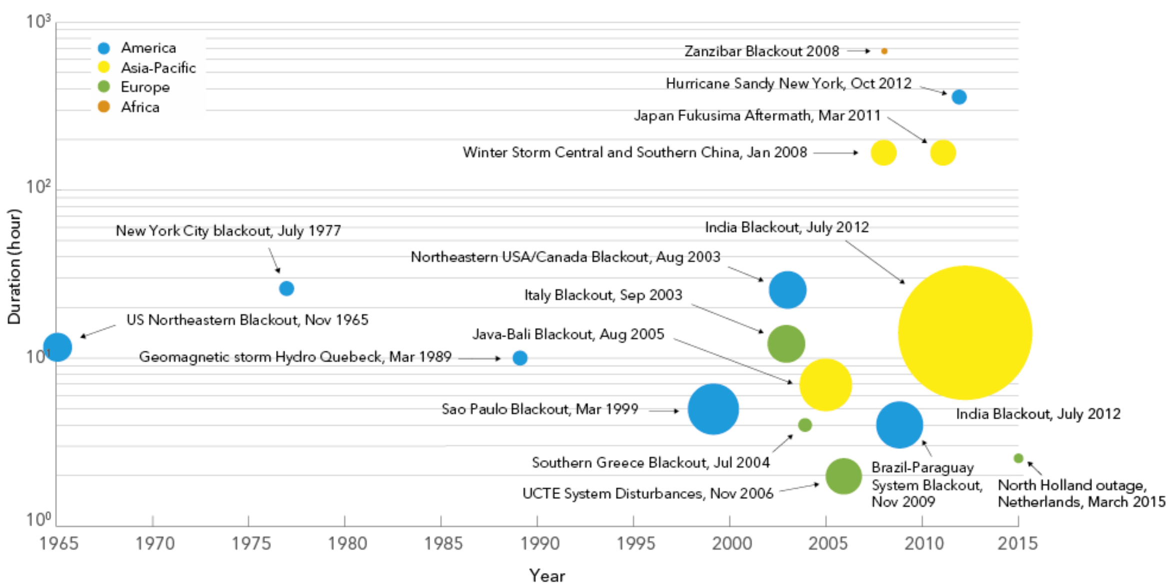


Figure 6: Major Global Power Outages, 1965 to 2015[40]*.*

[40] Peter Vaessen, 'De Betrouwbaarheid van Het Toekomstige Elektriciteitsnet Nationale Veiligheid En Crisisbeheersing', Nationale Veiligheid En Crisisbeheersing, 2015.

Therefore, in planning the deployment of the Energy Internet in Luxembourg, consideration should be applied for resiliency mitigation as a foundational component of engineering design principles, emergency response planning, and the formation of new approaches to electricity production and supply. Indeed, resiliency is inherently embedded in the considerations that are found in the subsequent proposals, particularly as it relates to increased integration of Luxembourg's bulk power systems with neighboring countries, as well as the adoption of distributed technologies such as microgrids and energy storage, and the application of experimental distributed grid clusters.

PROPOSALS

Enabling the Energy Transition in Luxembourg

The Energy Working Group proposed ten measures to further the transition to a TIR-compliant energy system. As shown in Table 3, the actions developed by the Working Group represent a broad range of measures. The shaded sections highlight our recommended subset of priority actions (within the next 10-15 years) in which Luxembourg can, and should, take a leadership role. These priority actions represent prerequisites for many of the other actions, some of which will largely be directed by initiatives and influences occurring outside of Luxembourg's control and/or jurisdiction (such as global technology innovations).

Table 3: Energy WG Proposed Actions

Action	Why Action Is Needed to Support TIR
1. Promotion of renewable energy through the adaptation of the **legal framework** and establishment of **simplified procedures**	Remove legal barriers. Enable technological evolution and competitiveness. Simplify permit procedures. Simplify grid integration procedures. Allow access to biomass raw materials. Adapt land resource management procedures. Requires renewable energy system strategy.
2. Promotion of renewable energy, self-generation, and e-mobility through the adaptation of **funding programs** and/or **taxation schemes**	Enable investment in medium/large-scale renewable energy systems. Adapt tariffs to new market conditions. Establish tax/funding schemes to promote e-mobility. Direct funding for establishment of pilot clusters.

Action	Why Action Is Needed to Support TIR
3. Identification and promotion of **new business models** for energy services	Prepare legal frame to enable market development. Requires access to data. Requires consumer engagement.
4. Adaptation of **market designs**	Establish cost-optimal, flexible capacity markets. Design tariffs to reflect nature/cost of capacity. Create demand-side incentives.
5. First experimental **distribution grid cluster(s)**	Establish demonstration projects. Feature smart meters, grid, industry, and homes. Create systems to interconnect prosumers. Requires legal framework and financial support. Requires governance, clear goals, and accountability.
6. Promotion and development of **new technologies**	Enable storage flexibility through use of gas grid. Implement large- and small-scale projects. Requires more flexible/adapted legal frameworks.
7. Develop incentives/regulatory and economic frame for the operation of **electricity storage**	Covers both central and distributed systems. Enable balancing of flexibility needs. Requires open market/appropriate pricing signals.
8. Optimization of **CO_2 trading mechanism**	Adapt existing scheme or tax CO_2 emissions. Price fossil fuels, reduce renewable subsidies. Requires international consensus.
9. **Adaptation of grid** (data and electricity heat/cooling)	Invest to support high penetration of renewables. Address integration challenges. Develop communication/management systems. Adapt legal framework. Requires new market design.
10. **Heat recuperation** in industrial, commercial, and residential buildings	Increase recuperation efficiency (>90%). Enable energy efficiency in buildings. Support grid balancing activities. Requires new market design.

We have organized our discussion of these priority areas in the following sections:

- Market Design and Regulatory Framework (action #4)
- New Business Models and Financial Schemes (actions #2 and #3)
- Experimental Distribution Grid Clusters (action #5)

Market Design and Regulatory Framework

The TIR vision for the Luxembourg energy sector recognizes the importance of distributed and democratized resources, services, and processes. This concept largely depends on creating and enhancing networks and reducing regulatory barriers that interfere with innovation.

The energy market landscape has shifted considerably over the past decade. The changing environment within the electricity market is being influenced by a number of key factors: the changing consumer; evolving technology; entry of new players; and the provision of new product and service offerings. Customers are reducing energy use and switching to new energy efficient appliances to avoid the increase in electricity prices. Households are installing solar rooftop and community-based PV systems, and energy intensity from Luxembourg's commercial and industrial sectors has declined due to recent energy efficiency measures.

To prepare for the future, energy markets and regulations will need to become more agile to accommodate new players and the changing roles of existing players. The future energy system will require increased energy visibility to allow for informed choices and assessment of energy management capabilities (e.g., benchmarking, feedback systems). The future system will also require new physical networks and linkages to allow for grid flexibility and emerging concepts, such as transactive energy.[41]

Luxembourg will need to strike a reasonable balance of adaptability and reliability within its energy sector governance and regulatory frameworks. This will be especially important during the next few decades, as demonstration projects begin to provide the evidence needed to inform policy at the scale envisioned for the TIR.

Below we summarize our interrelated, high-priority proposals supporting market design and regulatory frameworks:

- USEF: One common standard to enhance value creation

[41] *Transactive energy* refers to techniques for managing the generation, consumption, or flow of electric power within an electric power system, through the use of economic or market-based constructs, while considering grid reliability constraints. GridWise Architecture Council, http://www.gridwiseac.org/about/transactive_energy.aspx.

- Further development of integrated wholesale European and secondary markets
- Enhancing retail competition
- Decision support for future energy system design

USEF: One Common Standard to Enhance Value Creation

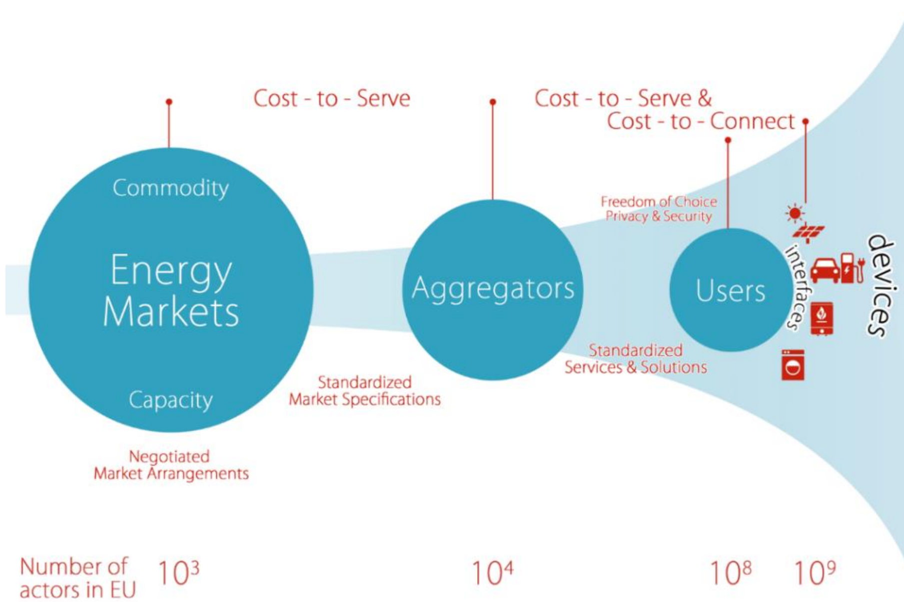
Innovation is occurring rapidly, yet markets differ and multiple initiatives are underway at the same time in different places. While we accept that this approach may be the fastest way to get results, without any uniformity, there is a risk that initiatives will not be compatible or connectable. Standardization, with specifications for market access and interoperability, is a prerequisite for the establishment of an accessible, flexible, and truly integrated energy market. To achieve this effectively requires that we work together and think beyond existing market positions, companies, regions, and countries.

The Universal Smart Energy Framework (USEF)[42] presents a market structure, shown in Figure 7, for the trading of flexible energy use and the tools and rules to make it work effectively. By providing a common standard on which to build, it ensures that people, projects, and technologies can be connected for an integrated smart energy future that is energy efficient and cost-effective. The framework specifies all market roles, how they interact, and how they can benefit by doing so.

USEF aligns the trading of consumer flexibility with existing wholesale market models. By extending standard key processes to include usage prognoses for individual consumers, USEF fits on top of, and can integrate with, most market models.

[42] USEF has been developed to accelerate the smart energy transition and unlock the value of prosumer flexibility by incentivizing all stakeholders (new and traditional) in the energy system. The USEF Foundation is a partnership organization comprised of ABB, Alliander, DNV GL, Essent, IBM, ICT and Stedin. For more information, see http://www.usef.energy.

Figure 7: Standardized Market Access Is Required for Acceptable Cost to Connect and Cost-to-Serve



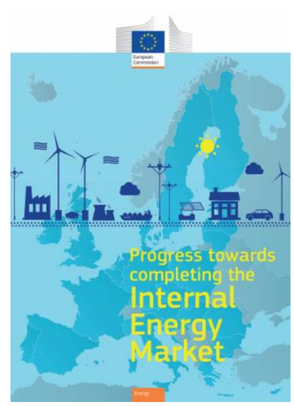
USEF's open ICT architecture provides the freedom to create unique and commercially competitive smart energy products and services while delivering a common standard on which to build them. The smart energy market will see existing roles adapted and new market functions created. By defining the roles, responsibilities, and interactions required, USEF enables parties to both understand and realize smart energy opportunities.

By delivering a common standard to build on, USEF reduces the cost to connect different technologies and projects to the energy system. Its market-based control mechanism then defines the rules required to optimize that whole system, ensuring that energy is produced, delivered, and managed at lowest cost.

USEF offers the market description with specifications, designs, and implementation guidelines. With its reference implementation and the knowledge from pilots, USEF further supports future users with insights, structure, and exemplary coding. With detailed specifications and real-life pilots, USEF is perhaps the most comprehensive and advanced initiative of its kind.

Development of an Integrated Wholesale European Market and Secondary Markets

Over the last two decades, Europe's energy policy has consistently been geared towards achieving its main objectives: affordable and competitively priced, environmentally sustainable, and secure energy for everybody. A single, well-integrated internal European energy market is seen as a fundamental prerequisite to achieving these goals.[43]



Integration of regional markets is currently in progress. However, building out of interconnectors and regulatory frameworks to support harmonized market rules will need to continue to evolve on a regional and EU-wide level.

Luxembourg is already fully integrated into the German electricity price zone. As a result, there is no domestic electricity wholesale market in Luxembourg. Moving forward, Luxembourg should consider its position in the evolving European integrated electricity market to ensure the country is well-optimized for the future and is aligned with its Third Industrial Revolution energy vision.

Larger, interconnected bulk power markets can lead to increased efficiency in planning for new transmission investment and maximizing capital spending across national boundaries. These markets also create efficiencies in maintaining grid reliability, dispatching the most cost-effective power generation (and DR resources) that further directs investment into more efficient power production technology over time. Indeed, these are the principles espoused by ENTSO-E.[44]

Furthermore, a number of new secondary market models are being tested in Europe, including local flexibility markets and flexibility contracts with aggregators. These models are required to address a new energy mix, new consumption patterns (e.g., e-mobility), and the movement towards consumers becoming prosumers.

Major energy companies, such as RWE in Europe, are moving aggressively in this emerging landscape, taking advantage of opportunities to integrate DER and DR, while remaining flexible to adapt new, emerging technologies (e.g., solar power combined with battery storage) that have not yet been commercialized to scale.

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[43] European Commission. "Progress towards completing the Internal Energy Market". 2014. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_iem_communication_0.pdf

[44] ENTSO-E. "Who Is ENTSO-E?" 2015. Available at: https://www.entsoe.eu/about-entso-e/Pages/default.aspx

Luxembourg should take a holistic approach to planning a market that is fit-for-purpose. This would include orienting its market arrangements to support the development of emerging technologies that enable unique services and capabilities, layered into the system.

Enhanced Retail Competition

In the electricity and gas supply chains, the retail market includes the provisioning of energy to end-use customers. The retail energy market provides customers with the ability to purchase energy services from licensed/accredited retail businesses of their choice. To support this choice, the retail market provides the systems and processes to track and support the relationships and flow of information between retailers, distributors, and customers, to ensure that customer transfers can take place and that costs in the supply chain are correctly allocated and billed.

In Luxembourg, the supply market is fully open to favor competition and to be attractive to additional suppliers. Nevertheless, the market is dominated by the national champion Enovos Luxembourg.[45] Such a structure can provide advantages as well as risks for competitive and efficient market development. Enovos' retail market dominance should be monitored in the light of transparency, competitive neutrality, and other competition issues. Luxembourg has the third lowest switching rate in the EU, despite the country being ranked sixth in the EU for ease of switching. Studies show that one reason for the low level of switching is the high customer satisfaction. Luxembourg should work on further enhancing competition.

Finally, a retail market assessment should be considered simultaneously with the evolution of wholesale markets. There are strong links and interplays between the wholesale and retail markets, with the competitiveness of each segment influenced by the respective market arrangements. For example, a competitive retail electricity market is influenced by the nature of the wholesale arrangements and the ease of entry and operation. This includes the ability to access generation at a competitive price; the ability to manage market risk, simplicity, and clarity of the regulatory framework and market interfaces; the nature of the hub balancing arrangements; access to timely and accurate data; transparency and symmetry of market information; or the nature of the wholesale settlement arrangements. These factors are similarly relevant in natural gas markets.

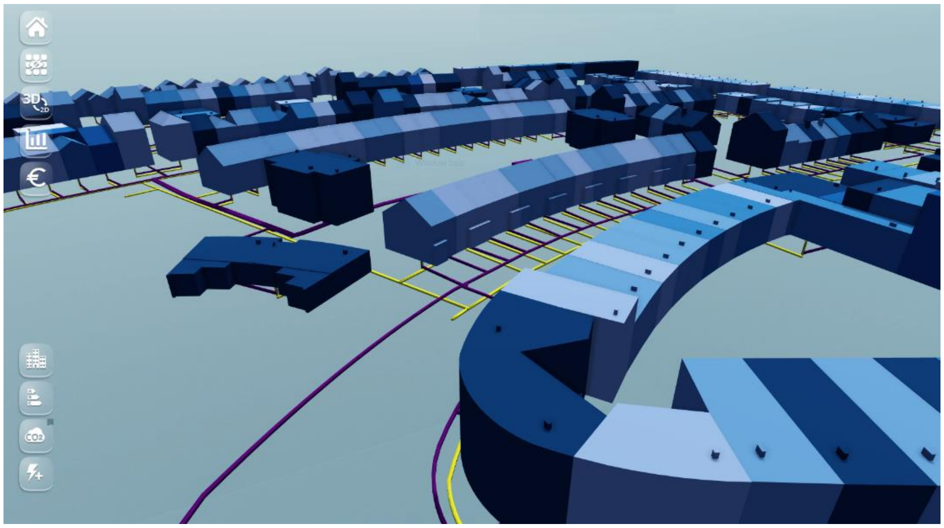
[45] International Energy Agency (IEA). "Energy Policies of IEA Countries – Luxembourg 2014 Review" 2014. Available at: http://www.iea.org/publications/freepublications/publication/energy-policies-of-iea-countries---luxembourg-2014-review.html

Decision Support for Future Energy System Design

Transitioning toward a fully TIR-enabled Energy Internet in Luxembourg involves invasive processes, where many high-impact decisions (with long-term consequences for all stakeholders) have to be made. As such, we recommend completing a number of intermediary initiatives to provide strategic guidance and operational support:

- **Scenario analysis.** There are many conceivable and potentially viable ways to transition to a carbon-free energy system in 2050. The exact components of that system depend on many societal, political, economic, and technological factors and are therefore extremely difficult to predict. In order for Luxembourg to make the right choices at the right time, and to be able to identify the no-regret and high-risk options at any point in time during this transition, further analyses are necessary to identify and assess a set of scenarios that contain all conceivable ingredients of the energy transition. These analyses can yield the most feasible transition paths and actions to be taken by Luxembourg, to optimally manage the energy transition.
- **Stakeholder analysis.** Additional analysis should be conducted to outline the implementation of commodity and flexibility markets and supporting regulation, such that both existing and new players in this market have equal access and fair market conditions. For the energy transition to be a success, stakeholders of all sizes have to be able to participate against acceptable costs-to-connect and costs-to-serve. These requirements mandate a scalable solution, both in scope and number of participants, which recognizes the different stakeholders and their role in a smart energy system. Freedom of connection, transaction, and dispatch should be guaranteed, and the implemented solution should align well with European wholesale markets.
- **Modeling platform.** A modeling platform is needed to ensure that at any point during the transition, the best possible decisions can be made, and that these decisions are powered by the most complete and available data and their effects can be effectively communicated to all stakeholders. Such a platform should feature components for detailed, multi-commodity load flow planning and optimization, grid capacity planning, and conversion and energy storage options. The platform should allow for analysis of “what if” scenarios and benefit/cost analyses on both the national and local level. Integration with open data sources should be possible to make use of best available data. Spatial planning aspects should be incorporated via dashboards and 3D visualization features. An example of this visualization is shown in Figure 8.

Figure 8: Visualization of CO_2 Production in a Traditional Neighborhood Heated by Natural Gas (Lighter colors indicate lower values)



New Business Models and Financial Schemes

The energy sector is transforming to more effectively encompass new technologies and solutions. It also includes advanced software and hardware to enable greater control and interoperability across grid elements. All of these components are operating within an Internet-enabled free market, where it is envisioned that technologies and grid systems can be automated to barter over the proper way to solve mutual problems, and settle on the proper price for their services in near real-time.

Commonly referred to as transactive energy platforms, these systems represent a way of creating a level playing field for producer (as well as consumer) investment decisions. In these types of systems, all parties act autonomously and there is an expectation of transparency; regulators oversee the system to prevent abuse. Standardized platforms can be local or span large regions (e.g., neighborhoods, municipalities, countries).

These platforms are being tested—along with the market and regulatory changes previously discussed—in demonstration settings throughout Europe and other jurisdictions. Through these projects, new business models and financial schemes are emerging. A summary of these emerging models are provided, along with a specific proposal, in the next section, to establish funding mechanisms for accelerating the sustainable technology (SusTech) sector in Luxembourg.

Public and Private Sector Financing Models

One of the most common options for accelerating investments in DG is the use of Feed-in Tariffs (FiTs), which typically subsidize the initial cost of installing renewable energy systems at the consumer level. FiTs have been in operation in Luxembourg for the past decade,[46] cover a wide range of DG and renewable energy technologies, and have recently been expanded to support the development of community-scale, renewable energy projects.[47] A system of premium FiTs has been shown to be an effective instrument to promote the generation of renewable electricity; notably, to ensure a low-level market adoption of wind and solar power at the national level. In the longer term, however, such a system is hard to sustain due to its distortive pricing impacts and, ultimately, incompatibility with the creation of a single, liberalized electricity market in Europe. Taking this and the current technology maturity levels for wind and solar PV into account, FiTs for these types of renewable energy systems are not likely to be a key part of Luxembourg's future smart energy system design.

Additional business models and financial schemes are emerging in Luxembourg to support the development of energy cooperatives. Following success in other European markets, notably Germany, Denmark, and Italy,[48] energy cooperatives can take several forms. These forms range from development of small-scale renewable energy assets to serve a part of a community's energy needs, to full-scale, municipality-owned and operated generation and distribution facilities. Other initiatives are experimenting with crowdfunding platforms (Citizenergy)[49] and performance contracting and third-party financing models (CITYnvest).[50]

We note that Luxembourg has a few relevant projects underway, namely Enercoop TM[51] and EquiEnerCoop,[52] which aim to promote, support, and provide advice on establishing cooperative energy systems. More cooperative models are emerging and should continue to be encouraged through public/private partnerships.

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[46] International Energy Agency (IEA). "Energy Policies of IEA Countries – Luxembourg 2014 Review" 2014. Available at: http://www.iea.org/publications/freepublications/publication/energy-policies-of-iea-countries---luxembourg-2014-review.html

[47] See announcement at https://www.wort.lu/en/business/from-january-1-2016-new-solar-feed-in-tariffs-in-luxembourg-55bf68590c88b46a8ce5dc45

[48] European Commission. "RESCOOP European Projects". May 2016. Available at: https://rescoop.eu/participation-rescoops eu-projects

[49] See https://citizenergy.eu/

[50] See http://www.citynvest.eu/

[51] ECI Transition Minett. "La Transition Energetique". 2016. Available at: https://www.transition-minett.lu/groupes/tmenercoop

[52] EquiEnerCoop. "EquiEnerCoop – Société Coopérative". 2016. Available at: http://www.equienercoop.lu/statuten/

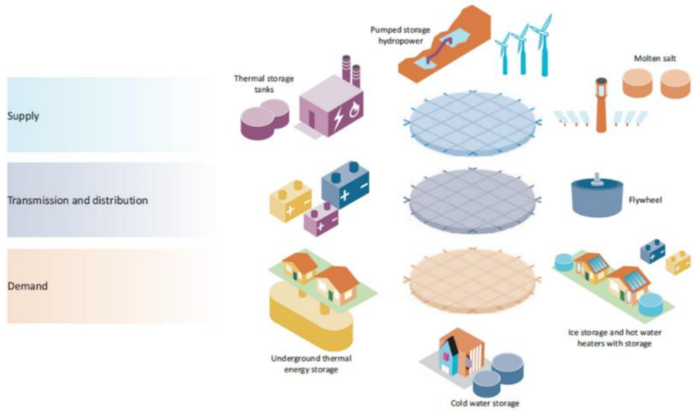
New financing models are also evolving in support of technologies that enable the development and integration of other forms of DER, such as distributed energy storage and microgrids.

- **Energy storage.** In order to integrate a large capacity of renewable energy, Luxembourg should consider increasing its supply of energy storage beyond its existing pumped storage capacity. Financing structures for energy storage are rapidly evolving, and Luxembourg should encourage a range of development and ownership models, some of which are summarized in Table 4.

Table 4: Energy Storage Offers and Ownership Models

Storage Developer: Offers	System Ownership
Shared Savings Model	Third-Party Owner (TPO)
Sale/Lease + Host Control	Host Owned
Utility Procurements	Third-Party Owner (TPO) Utility-Controlled
Sale/Lease + Utility Tariff Rate	Host Owned Utility-Controlled

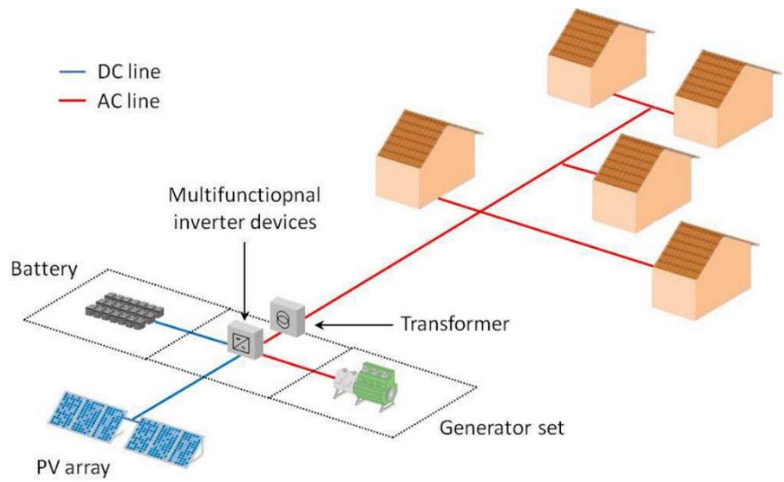
Figure 9: Hypothetical Deployment of Storage Assets Across a Power System [53]



- **Microgrids.** As energy storage is deployed, we recommend evaluating each installation for the opportunity to create a building- or community-level microgrid. A microgrid is not a single technology, but rather a system of systems, as illustrated in Figure 9. Since microgrids can be deployed as a shared asset within a group of buildings or in a community, new financing mechanisms will be required to enable adoption. One option is that the distribution utility owns and operates microgrids and includes them in their tariff structure for cost recovery purposes. Another financing option can occur through third-party leases. Finally, government agencies could sponsor their development and operation, which is happening with municipalities in parts of North America, as a resiliency option to mitigate large power outages resulting from extreme weather events. Another relevant type of microgrid financing option for Luxembourg could be the community microgrid, as illustrated in Figure 10. These arrangements enable local community homeowners and businesses to economically share in the development, ownership, and operational costs for microgrids. Many of these systems are deployed throughout Europe due, in part, to a retail competition framework that is more advanced than other parts of the world.

[53] International Energy Agency. IEA "Energy Storage Roadmap". Available at: https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergystorage.pdf

Figure 10: Schematic View of a PV/Storage Hybrid System for Community Grid Electrification



Action Plan for SusTech Sector Financing

The development of a SusTech sector—analogous to Luxembourg's financial technology (FinTech) sector—would not only aid in the transition from the current fossil-fuel based economy to an economy powered by sustainable energy. It would also result in job growth for both vocational and knowledge workers. The energy transition requires ongoing development in the area of energy conversion and storage technologies, as well as experimentation with new products and services enabled through advancements in smart grid infrastructure. Enabling a SusTech sector within Luxembourg will assist in the creation of new economic activity and build new businesses locally (as opposed to importing). The development of a viable SusTech sector in Luxembourg can be supported through projects recommended by the Finance WG (e.g., the use of blockchain technology, the establishment of a secure data vault for smart contracts).

However, two challenges will need to be addressed if this vision for Luxembourg's SusTech sector is to be realized:

- **Increase R&D expenditures.** R&D intensity in Luxembourg, as measured by R&D expenditures as a percentage of GDP, has been declining since the turn of the century.[22] While public R&D intensity has increased, business R&D intensity has dropped dramatically, as has the sum of the two. This trend will have to be reversed if a viable SusTech sector is to be created.
- **Create a favorable environment for entrepreneurship.** The Finance Working Group has identified the need to further encourage development of the entrepreneurial culture in Luxembourg.[22] While initiatives to encourage startups and draft legislation to facilitate

business creation have been put in place, Luxembourg's regulatory restrictions should be reviewed in order to create a more attractive environment.

Fostering a climate toward a more entrepreneurial culture in which the SusTech sector can flourish takes time and effort. If Luxembourg desires to become a leader in sustainable technology, a dedicated action plan addressing investments, education, and business culture is strongly recommended.

This SusTech action plan can address the type of investment, education, and business culture that will be needed for Luxembourg to become a leader in sustainable technology. In addition, lessons learned and best practices from Luxembourg's FinTech sector, as well as from current leaders in sustainable technology and leading entrepreneurial regions, can be incorporated into the action plan.

The action plan can result in a charter for a public-private partnership that leads to the creation of a flourishing, and well-funded, SusTech sector in Luxembourg. Funding options like a Knowledge and Innovation Community (KIC), co-funded by the European Institute of Innovation and Technology, can be considered to kick-start SusTech in Luxembourg.

Experimental Distribution Grid Clusters

Across Europe, there has been thousands of practical demonstration projects designed to experiment with new energy business models, deploy advanced energy infrastructure, and adapt traditional regulatory frameworks.

For example, blue-sky projects—such as the European Commission's Horizon 2020 and Intelligent Energy Europe (IEE) initiatives—are seeking to experiment and test more advanced energy concepts. These projects are building a critical R&D mass, the development of which will accelerate the advancement of the longer-view TIR vision. There have been more than 2,500 projects implemented as part of the European Federation or Renewable Cooperatives (REScoops) initiative.[54] In these projects, citizens are actively engaged not only in renewable electricity production, but also in heat production in district heating cooperatives. All these REScoops are bringing benefits to their local economies and are helping the EU to reach its renewable energy and energy efficiency targets. Other

[54] European Commission. "RESCOOP European Projects". May 2016. Available at: https://rescoop.eu/participation-rescoops-eu-projects

projects aim to develop, deploy, and evaluate advanced tools and ICT services for distribution grid operators, production cooperatives, and medium-sized retailers (Nobel Grid),[55] while others are focused on experimenting with cooperative models for district heating companies (Smart Reflex).[56]

Together, these community renewable and energy efficiency projects are examples of successful projects that encourage citizens to cooperate in the development of renewable energy and energy efficiency initiatives. The results are compelling: European cooperatives have made cumulative investments of €977 million between 2012 and 2014. Together, they attracted 109,801 new members and, in 2014, produced around 129,050 toe/year of renewable energy.[57]

While these initiatives are providing important early learnings from largely small-scale experiments, they lack the scale necessary to provide sufficient evidence to inform Luxembourg's future energy policy at the national level. The following section provides a recommendation for Luxembourg that can create an experimental grid cluster large enough to inform decisions at the distribution system operator (DSO) level, and possibly at the EU level.

First Nationwide Smart Grid

The European Climate Change Programme[58] aims to provide reliable and affordable energy for all, to apply the efficiency first principle, and to make the EU the global leader in renewable energy.[59] The EU's energy and climate objectives for 2030 are expected to increase the share of renewables to up to 50% of total electricity produced. "Achieving these goals will require a fundamental transformation of Europe's energy system, including the redesign of the European electricity market"[60] by providing greater predictability, linking the wholesale and retail markets, and attracting further investments. This will contribute to delivering a new deal for Europe's energy consumers.

To achieve that objective, the European Commission needs to demonstrate this new energy system in practice. Such a demonstration environment requires a combination of an energy system with a high degree of renewable energy production, and the simultaneous development

[55] See http://nobelgrid.eu/
[56] See http://www.smartreflex.eu/en/home/
[57] European Commission. "Energy cooperative projects celebrate 10 years of the UN's International Day of Cooperatives". July 2015. Available at: https://ec.europa.eu/easme/en/news/energy-cooperative-projects-celebrate-10-years-un-s-international-day-cooperatives
[58] See http://ec.europa.eu/clima/policies/eccp/index_en.htm and links therein.
[59] See http://ec.europa.eu/clima/policies/eccp/index_en.htm and links therein.
[60] https://ec.europa.eu/energy/en/news/new-electricity-market-consumers

of a smart energy system that interconnects these energy sources. Although, as outlined above, many demonstration projects are already developed (or under development), none of them has a significant scale with an integrated solution that combines the requirements of all the stakeholders.

The scale of such a demonstration project should be at least 100,000 end users, both commercial & industrial (C&I) and residential, before it would provide sufficient proof to both the EU, and especially to the DSO that need to optimize the solutions, and evaluate the effectiveness of such solutions on their networks. Before implementing this throughout Europe, significant and hard evidence is required.

Luxembourg should take on this experiment and demonstrate this new market model for Europe (i.e., the first nationwide smart grid). This, in turn, would establish Luxembourg as the first mover and attract many new, smart energy businesses. European funds (e.g., Horizon 2020) would surely be available to support this initiative and, ultimately, European energy policymaking would benefit from the scale of the evidence base provided.

In addition, the scale of this experiment would aid in catalyzing Luxembourg’s journey towards commercializing the smart energy business. Luxembourg would effectively become the smart energy transaction hub for Europe, enabling many new smart energy FinTech products for export throughout Europe.

Summary of TIR Proposals for Energy

The following summarizes our proposals for the TIR roadmap for Energy. We have organized them into two broad groups:

1. **Building Block Proposals.** The Building Block Proposals summarized in this section build from the work initiated by the Energy WG, and discussed in detail in the preceding sections. These proposals represent our recommended subset of priority actions (within the next 10-15 years) in which Luxembourg can, and should, take a leadership role. These priority actions (building blocks) represent prerequisites for many of the other actions, some of which will largely be directed by initiatives and influences occurring outside of Luxembourg’s control and/or jurisdiction (such as global technology innovations).
2. **Innovation Proposals.** The Innovation Proposals summarized in this section are conceptual ideas to foster the vision, goals, and actions described in the TIR roadmap for Energy. These Innovation Proposals are predicated on the assumption that, over time, Luxembourg would apply increased research and development investments into targeted measures, rather than in general studies. Furthermore, Luxembourg’s aim to

increase incubated and entrepreneurial businesses provides a supporting platform for many of these proposals.

In addition, we have organized these proposals according to how they fit within seven broad categories: regulatory; public policy; financial; technical; business model innovation (BMI); educational; and research, development, and innovation (RDI). Many proposals cut across multiple categories. As shown in Table 5, a 'P' indicates the primary category to which we have assigned a proposal and an 'S' indicates assigned secondary categories. We have also highlighted, where appropriate, how the proposals overlap with other TIR Pillars (e.g., Smart Economy, Mobility).

Building Block Proposals

Regulatory

- **Implement a common standard to enhance value creation within the smart energy ecosystem.** Standardization, with specifications for market access and interoperability, is a prerequisite for the establishment of an accessible, flexible, and truly integrated smart energy marketplace. A common standard is needed to enable trading of flexible energy use, and to ensure that the tools and rules to make it work are effective. This standard would also need to specify all market roles, how they interact, and how they can benefit by doing so. A common standard also reduces the cost to connect different technologies and projects to the energy system. The USEF, as one example, provides the key elements required, such as the market description, with specifications, designs and implementation guidelines; implementation references and knowledge from pilots; and a range of insights and support tools (e.g., exemplary coding). Other examples of common standards are also available and under development.

TIR Proposals for Energy	Proposal Category (P = primary category and S = secondary categories)							Overlap with Other TIR Pillars
	Regulatory	Public Policy	Financial	Technical	BMI	Educational	RDI	
hardware/software systems and controls equipment								
Create an R&D test bed for advanced power generation and energy storage options				P			S	
Creation of smart meter data repositories to facilitate innovation in energy pricing and service offerings	S		S	P	S		S	Buildings, Finance, Prosumers, Smart Economy
Support two-way charging infrastructure for electrical vehicles and monitor developments for expanding hydrogen infrastructure	S		S	P	S			Finance, Industry, Mobility, Prosumers, Smart Economy
Facilitate the development of standards with regard to network orchestrator platforms and business arrangements (eco-orchestrator)	P	S	S	S	S		S	Finance, Mobility, Prosumers, Smart Economy
Create a smart governance oversight body and develop/implement appropriate performance assessment tools		P	S	S				Finance, Smart Economy
Create a 'Future Transport Fuel' platform and cargo transport decarbonization roadmap		P	S	S			S	Finance, Industry, Mobility
Develop innovation engines for accelerating zero net neighborhood (ZNN) models		P	S	S			S	Buildings, Circular Economy, Finance, Mobility, Prosumers, Smart Economy
Focus on schools as engagement hubs		P	S	S			S	
Develop an XPRIZE type of approach to stimulate interest and test a comprehensive range of implementation options		P	S	S			S	
Establish integrated design principles as a requirement for eco-district funding		P	S	S			S	

TIR Proposals for Energy	Proposal Category (P = primary category and S = secondary categories)							Overlap with Other TIR Pillars
	Regulatory	Public Policy	Financial	Technical	BMI	Educational	RDI	
Implement partnerships with large businesses to promote energy-at-work initiatives		P	S	S		S		Buildings, Prosumers, Smart Economy
Upgrade information and engagement: mySMARTenergy		P	S	S	S	S		Buildings, Circular Economy, Prosumers, Smart Economy
Develop innovative disclosure and rating tools for the real estate sector		P	S	S		S		Buildings, Prosumers, Smart Economy
Foster lifelong learning to keep pace with the evolving needs of the energy transition		S	S	S		P		Buildings, Smart Economy

Additional elements of this proposal include:

- **Closely follow standardization efforts. Influence, but don't lead.** The challenge with a new energy market and energy system is that there is no common agreement yet on which standards and approaches should be applied. There is a risk of "betting on the wrong standard," resulting in loss of time and investments as developing standards can take a long time. Years will pass between obtaining formal approval and adoption of the standard and acquiring sizeable market share. Therefore, Luxembourg should closely monitor international developments in smart energy system standardization, rather than proactively trying to set new standards and approaches. Luxembourg should take timely steps to ensure that learning from its demonstration projects is brought forward and included in the appropriate standardization discussions.

- **Local implementation to follow local requirements.** When relevant international approaches, standards and European regulations have been identified, these need to be embedded in the local context of national standards and regulations. Alignment of the local processes and procedures in cities and municipalities is essential to pave the way for deployment of a Third Industrial Revolution energy paradigm in Luxembourg. Close collaboration with industry partners will ensure that the local standards and regulations align with the latest industry standards and guarantee a smooth and safe introduction of the TIR energy system and market. A consistent national approach is the key to a swift development of an interoperable Third Industrial Revolution energy system.

- **Massive change requires massive accreditation.** In order for Luxembourg's new, highly dynamic energy regime to work safely, reliably and efficiently, it is of utmost importance that all distributed energy production and consumption components seamlessly fit together, speak a common language, and perform according to their claims. The process of standardization, certification and monitoring helps to ensure the interoperability of the individual components in the most cost effective way. When embarking on such a transition, a multitude of components, systems and projects will need to be certified. Luxembourg should ensure it has access to sufficient accredited certifiers to accomplish this task.

- **Support the development of an integrated wholesale European energy market and secondary markets.** A well-integrated, single internal energy market is seen as a fundamental prerequisite to achieving Europe's energy policy objectives of affordable and competitively priced energy, which is both environmentally sustainable and secure for everybody. While the integration of regional markets is currently in progress, Luxembourg should take steps to build out interconnectors and regulatory frameworks, and support the development of harmonized market rules, to continue to evolve the energy ecosystem on a regional and EU-wide level. Luxembourg should encourage energy companies to move more aggressively into local flexibility markets and develop a broader range of flexibility contracts with aggregators. These models are required to address a new energy mix, new consumption patterns (e.g., e-mobility), and the movement toward consumers becoming prosumers.

- **Assess the benefit/cost tradeoff from enhanced retail competition in Luxembourg.** In Luxembourg, additional initiatives should be analysed to foster the case for transparency and more competitive pricing. The retail energy market of the near future will also need to be flexible enough to accommodate new market entrants and emerging energy as a service business models. Retail markets should also be assessed with the evolution of wholesale markets, as there are strong links and interplays among the underlying market structures.

- **Decision support is needed to enable the design of Luxembourg's future smart energy system.** A number of intermediary initiatives are recommended to provide strategic guidance and operational support, as Luxembourg embarks on this important energy transition. These recommendations include scenario analysis to identify optimized action pathways, stakeholder analysis to ensure scalable solutions involving stakeholders of all sizes, and modeling platforms on which to visualize impacts from different tradeoffs at the national and local level.

Public Policy

- **Support the development of Europe's first nationwide smart grid.** While thousands of innovative demonstration and pilot projects are underway throughout Europe, these initiatives are essentially small and lack the scale necessary to provide sufficient evidence to inform Luxembourg's future energy policy at the national level. Luxembourg should seek European funding to implement a much larger project (e.g., 100,000 customers or more) and establish itself as a first mover at this scale. Such a project would attract many new, smart energy business activities to Luxembourg, kick-starting a journey towards commercializing the export of smart energy solutions to the rest of Europe and elsewhere.

Financing

- **Develop alternatives to FiTs for accelerating investments in DER.** This will include public support for scaling the concept of energy cooperatives, crowdfunding platforms, and other sharing models. Innovations in performance contracting and third-party financing models should also be supported through public funding initiatives (i.e., incentives). New financing models should also be supported through public/private partnership, such as those that enable the development and integration of DER (e.g., distributed energy storage, microgrids).

- **Develop and implement an action plan for financing Luxembourg's SusTech sector.** Analogous to Luxembourg's FinTech sector, fostering Luxembourg leadership in in SusTech would aid in the transition from the current fossil-fuel based economy to an economy powered by sustainable energy. It would also result in job growth for both vocational and knowledge workers. Attaining leadership in this area will require increased R&D expenditures in the public and private sectors, as well as the creation of a more favorable environment for entrepreneurship. The action plan should include a charter for establishing a public/private partnership to ensure adequate funding is made available and secured over time.

Innovation Proposals

Technical

- **Develop the energy superhighway.** The energy superhighway is a crucial element of the larger Energy Internet. The importance of interoperability and coordination with entities and infrastructure, such as smart cities, smart buildings, DER, and electric transportation, cannot be understated. This proposal seeks to increase transactional linkages among transmission operators, distribution operators, energy suppliers, third parties, and all of their associated systems. Additional elements of this proposal include:
    - **Develop a scalable network of DER technologies that can be monitored, controlled, and dispatched as a virtual power plant.** Software control development is greatly needed to support this integration and dynamic interplay between DER technologies. Current examples can be found in California, where distributed energy storage technologies are being aggregated and deployed in an interconnected fashion, enabling the reduction of peak power demand on the

regional power grid, thus avoiding the use of fossil-fueled power generation during extreme temperatures.

- **Accelerate smart meter-enabled, network applications beyond business as usual.** As Luxembourg advances its plan to roll out smart meters in 2016, consideration should be given to the emerging next-generation advancements in network applications that will be facilitated by the installation of smart meter technologies at scale. These advancements could accelerate more common applications, such as conservation voltage reduction, load balancing, outage management, transformer overload detection, high impedance fault detection, and other applications.

- **Develop a national testing laboratory for cyber security validation of hardware/software systems and controls equipment.** The idea is to identify and alleviate potential risks and concerns with distributed intelligence in building systems, energy systems, and mobility systems. This concept further leverages the recent Network and Information Security (NIS) Directive in Luxembourg, which has established security and notification requirements for Operators of Essential Services (OoES)—such as banking, energy, transport, financial market infrastructure, health, drinking water, digital infrastructure—and Digital Service Providers (DSPs), including online marketplaces, online search engines, and cloud services.This national lab could build on the competence center for (smart) metering already built up by Creos in Contern as well as institutionalize the ongoing collaboration between Creos' National Grid Control Center and the SNT department of the University of Luxembourg.

- **Create an R&D test bed for advanced power generation and energy storage options.** This could include new battery chemistries for energy storage, advanced power inverters for renewable energy, and hybrid systems to integrate multiple energy technologies, such as energy storage with renewables.

- **Creation of smart meter data repositories to facilitate innovation in energy pricing and service offerings.** Smart meter data exchange platforms can facilitate the development of innovative rate designs and related service offerings. Data privacy considerations will need to be addressed as different levels of access to these platforms is granted to new market entrants, and to other stakeholders over time.

- **Support two-way charging infrastructure for electric vehicles and monitor developments of hydrogen-based mobility.** Given the current and projected maturity, availability and uptake of full electric vehicles, supporting the creation of a two-way charging infrastructure should be characterized as a no-regret option. International developments regarding hydrogen-infrastructure should be closely monitored and facilitated, as appropriate. It is recommended to reduce further investment in fueling infrastructures for marginal fuels that are not carbon free, such as natural gas.

Regulatory

- **Facilitate the development of standards with regard to network orchestrator platforms and business arrangements (eco-orchestrator).** Increasing opportunities are emerging to exploit smart grid technology to optimize the energy use of consumers by automatically shifting local energy production from DER and microgrids, as well as energy consumption from intelligent energy devices like EVs, washing machines, water heating, and heat pumps. However, a broad range of standards are needed to facilitate further development of these opportunities. Luxembourg should support work to facilitate the development of these standards, as well as empower local network operators to pursue appropriate roles in moving this forward. Potential roles for the eco-orchestrator could involve tailoring electricity and gas supply, and demand services, for a customer, distributor, third-party energy provider, or grid operator.

  Similar network orchestrator business models can be found in other industries including Airbnb.com, WhatsApp, Uber, and Alibaba. Luxembourg-specific examples include Appartager, Carloh, BlaBlaCar, and others. To facilitate similar developments within the energy sector, Luxembourg should begin to explore the creation of a blockchain economic system for tracking energy transactions associated with transactive energy systems. This will also require coordination and integration with the systems of neighboring countries.

  Finally, an additional opportunity for Luxembourg is to develop advanced technologies for optimizing the water-energy nexus. A range of technologies are advancing to reduce water treatment and distribution consumption within the context of power generation, supply, and end use. These technologies range from more traditional waste heat recovery and process efficiency measures, to more advanced concepts like dry cooling and alternate fluids. In addition, cooling for thermoelectric generation continues to be an important target for water efficiency, as this process withdraws large quantities of water, resulting in wasted and untreated water, and consumes tremendous quantities of primary energy.

- **Require all critical Luxembourg City new or retrofit buildings to meet minimum resiliency standards.** Luxembourg City should include in its building design and energy codes, a strategy that also addresses the resiliency of specific buildings that are deemed critical for shelter and continued operations (e.g., hospitals, municipality, water/wastewater, police) during extreme weather or other related events. This can begin with the identification of critical buildings based on functionality, but also supplemented with a resiliency audit, to understand how impervious these buildings are to extreme weather events and other natural or man-made hazards (e.g., cyber attacks). This audit would also seek to identify cost-effective measures to improve resiliency of these buildings, while also reducing their energy consumption and GHG emissions.

For new buildings, the TIR recommendation is that Luxembourg evaluate and establish certain design requirements to incorporate a certain level of resiliency. In addition, Luxembourg City can lead by example, by having new or renovated City buildings become more resilient and disclose the resiliency measures of the buildings. Once this program is deemed successful in the city, then consideration can be made to scale it across the country to other metropolitan regions.

Public Policy

- **Create a smart governance oversight body and develop/implement appropriate performance assessment tools.** Smart governance will be critical to ensure that Luxembourg's journey through the Third Industrial Revolution proceeds in an efficient and cost-effective manner, thus avoiding wasteful or ineffective spending. Knowing where and when to focus investments and to initiate projects will enable a smoother transition. This proposal provides a strategy for identifying and prioritizing cities and/or regions according to their readiness for TIR investments and demonstration projects. This strategy includes an assessment framework for evaluating the readiness of cities and regions. This framework uses specific sets of criteria as measures of TIR readiness, as well as Readiness Benchmarks, against which cities and regional entities would be periodically evaluated. A Smart Cities Index[61] was recently developed for U.K. cities and provides a valuable model of this type of assessment framework.

- **Create a 'Future Transport Fuel' platform with partners from the European transport corridors, and begin building a detailed roadmap for decarbonizing cargo transport in Europe.** As Luxembourg's economy is intrinsically embedded in the European context, it is important that internal transport fuel and infrastructure policies are aligned with surrounding countries. Luxembourg might consider 'transition fuels,' such as biofuels

[61] See http://www.huawei.com/en/news/2016/5/UKs-leading-smart-cities

and LNG, with hydrogen and e-diesel options, which are becoming more favorable over time. In a transition to a fully sustainable transport economy, it will be crucial for Luxembourg to consider these options within the broader European context, and to establish and communicate clear goals and timelines.

- **Develop innovation engines for accelerating zero net neighborhood (ZNN) models.** This initiative focuses on implementing energy efficiency and renewable energy technologies at the neighborhood scale. It has several components:
  - **Focus on schools as engagement hubs.** By using schools as engagement hubs, this proposal increases energy awareness and creates a community-centered and location-based approach to energy efficiency and renewable energy that will generate replicable, medium-scale energy savings across a range of different sectors. In this way, schools take the lead in facilitating technological and cultural shifts that eventually become embedded in the community. Students and parents are afforded a unique opportunity to learn as part of a larger community. Social accountability is also maximized through the focus on the neighborhood as a geographical target. An initial ZNN would become a proof-of-concept that government would then replicate throughout other school districts in the region.
  - **Develop an XPRIZE[62] type of approach to stimulate interest and test a comprehensive range of implementation options.** Luxembourg should also develop a program to stimulate interest in expanding the ZNN concept beyond energy (i.e., include the circular and sharing economy, efficient transportation, and local entrepreneurship). The intent is to bring together neighborhood-scale microgrid technologies, smart meter-enabled energy feedback systems, and deep energy efficiency retrofits, to enhance community-level, renewable energy production, community engagement, and new business model development. Options might include traditional elements, such as energy audits and low-cost energy retrofits, but it can also go beyond traditional measures and include innovative concepts, such as the development of a residential microgrid using the local school as an engagement hub. In this example, the approach would generate a replicable, residential microgrid that balances the daytime energy demand of schools during the late afternoon, with the evening energy demands of households. Reductions in household- and school-related transportation energy consumption could also be considered through the promotion of efficient

[62] See http://www.xprize.org/ and links therein

transportation and mobility sharing schemes. Participation in these schemes might be encouraged through social accountability methods, as well as social norming processes. Limited-time discounts, financing, and other economic incentives can be provided by the government and third-party service providers (e.g., energy service companies), to discount the initial cost of participation and make implementation more affordable and risk-free.

  - **Establish integrated design principles as a requirement for eco-district funding.** Integrated design can transform the building construction process and help Luxembourg achieve its 2050 Vision for Energy. Integrated designs involve cohesive and collaborative planning, design, construction, and management of buildings to not only deliver on energy and environmental performance specifications, but to also increase occupant satisfaction and operational effectiveness. Requiring integrated design frameworks for public/private financing schemes will enable the necessary connections between each stage in the building lifecycle. They will also facilitate a closed loop information exchange between the design vision and ultimate use of the facility. These same principles should be integrated into other financing mechanisms, such as revolving loan funds and green investment bank type schemes.

- **Implement partnerships with large businesses to promote energy-at-work initiatives.** Luxembourg's national and/or local governments should partner with large companies to create employer-led programs that encourage and support employees to reduce energy consumption at work, and in their homes, and to install renewable energy technologies. Energy savings at work can focus on workplace employee engagement programs. Energy savings at home can be achieved through the provision of aggregated and discounted technology purchases, specialized payment programs (via the employer), energy information (in conjunction with Luxembourg's myenergy service), and tips and incentives (with normative and pro-social messaging and information about non-energy benefits), all intended to assist employees in changing energy consumption practices and reducing energy waste. The United Kingdom runs an employee awareness program called Carbon Trust Empower.[63] This program targets reduction in energy use, emissions, water, and waste through employee engagement. The program supports the development and implementation of an energy strategy, as well as the monitoring of the program.

[63] See https://www.carbontrust.com/resources/tools/empower and links therein

- **Upgrade information and engagement:** This proposal involves the creation of a national platform to provide real-time, historical, and comparative energy feedback to residential and commercial energy customers, using a web-based platform and in-home displays. The online information can utilize social norms and targeted tips to give meaning to energy consumption information and motivate action. This program can also enable residential and commercial customers to have access to near real-time energy consumption information. This information has been shown to effectuate consumer behaviors from increased energy visibility, to improve energy management and reduce energy consumption. Ideally, it can also provide historical consumption information, baseload and non-baseload information, time-of-use information, usage alerts, and a variety of other options that can help consumers become more knowledgeable and more effective in managing their energy consumption and reducing wasteful energy use. The information can highlight the non-energy benefits and pro-social benefits of energy efficiency technologies and smart energy practices, building on a waste management type of approach.

- **Develop innovative disclosure and rating tools for the real estate sector.** Making energy-related operating costs more transparent to owners, buyers, and renters creates an opportunity to make energy more visible and to reshape real estate preferences. Smart real estate markets will use comparative benchmarking and rating systems and ICT-enabled programs to share energy consumption information. In addition, there can be changes in real estate disclosure laws to promote reduced levels of energy consumption through participation in energy audits, appliance retrofits, smart energy management, green leases, and more. Public access to building-level energy consumption ratings (residential and commercial) can be accessed via a Zillow-type app, while actual consumption data can be a mandatory part of real estate transaction information sharing.

- **Develop, test, and maintain an electric power infrastructure resiliency strategy.** As previously suggested, a well-functioning electricity grid is a requirement to deliver critical services, including health services, transportation, and telecommunications. Due to the long term impact of investment decisions in power grid infrastructure, it is key that this infrastructure be explicitly addressed. It is recommended that Luxembourg's Energy working group focuses attention on defining scenarios for the future grid architecture, as well as develop a strategic response plan of action, in the event of extreme weather or cyber-related events that compromise the power network. As is the case for many TSOs and DSOs, emergency response plans also need to be tested and revised, as necessary, to account for new threats and mitigating solutions.

Educational

- **Foster lifelong learning to keep pace with the evolving needs of the energy transition.** Luxembourg can develop a public/private partnership funding and implementation scheme to expand the capacity for community engagement, education/workforce development, and building/industry audits. This can be created through a university/trade school extension service. The service can also create energy extension programs in select universities/trade schools that can provide training to students, while also providing information, community outreach, and onsite audit services to businesses, industries, and (potentially) households. The program can provide free or subsidized energy audits and advice concerning energy efficiency and renewable energy opportunities, and connect interested parties to pre-screened service providers.

MOBILITY

OVERVIEW

Co-Chairs Henk van Tuyl and Marie Sauvignon, and the Luxembourg Mobility Working Group;

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The meshing of the Communication Internet and the Energy Internet makes possible the build-out and scale-up of the automated Transportation and Logistics Internet. The convergence of these three Internets comprise the kernel of the Internet of Things platform for managing, powering, and transporting goods and passengers in a Third Industrial Revolution economy. The automated Transportation and Logistics Internet is made up of four foundational pillars, which, like the Energy Internet, have to be phased-in simultaneously in Luxembourg for the system to operate efficiently.

First, charging stations will need to be installed ubiquitously across land masses, allowing cars, buses and trucks, to power up or send back electricity to the grid.

Second, sensors embedded in devices across road networks as well as in vehicles will provide real-time data to help manage traffic flows, identify the best itineraries for automated vehicles, and provide information to the users (i.e. collective public transport information, car sharing and car pooling, etc.), and across logistics networks to allow factories, warehouses, wholesalers, retailers, and end users to have up-to-the-moment data on logistical flows that affect their value chain.

Third, the storage and transit of all physical goods will need to be standardized so that they can be efficiently passed off to any node and sent along any passageway, operating across the logistics system in the same way that information flows effortlessly and efficiently across the World Wide Web.

Fourth, all of the actors in public transport systems and along logistic corridors have to continue their efforts to operate synergistically and in coordination. By the end of 2017, all the public transport operators will provide a seamless public transport system based on interchange between different transports modes, with a single tariff system and travel document and coordination between the services. Operators along the transport corridors, in turn, need to continue to aggregate into collaborative networks to bring all of their assets into a shared mobility space to optimize passenger traffic and the shipment of goods, taking advantage of lateral economies of scale. For example, warehouses and distribution centers might establish cooperatives to share unused spaces, allowing carriers to drop off and pick up shipments using the most efficient path en route to their destination.

The Internet of Things platform will provide real-time logistical data on pick-up and delivery schedules, weather conditions, traffic flows, and up-to-the-moment information on warehouse storage capacities en route in Luxembourg. Automated dispatching will use Big Data and analytics to create algorithms and applications to ensure the optimization of aggregate efficiencies along the logistical routes and, by so doing, dramatically increase productivity while reducing the marginal cost of every shipment.

Globally, by 2020-2025, at least some of the shipments on roads, railways, water, and air corridors, as well as some of the movement of passengers, will likely be carried out by automated electric and fuel cell transport, powered by near zero marginal cost renewable energies, and operated by increasingly sophisticated analytics and algorithms. Driverless transport will accelerate productivity and reduce the marginal labor cost of shipping goods and moving people toward near zero on a smart automated Transportation and Logistics Internet.

Luxembourg already has a highly advanced and integrated logistics infrastructure upon which to build out and scale up an automated transportation and logistics platform. Cargolux, LuxairCargo, and CargoCenter provide world class service in air shipments, while CFL Cargo provides state of the art rail freight logistics, and CFL Multimodal provides a wide range of freight services. The Cluster for Logistics has been established to advance the various logistics services across Luxembourg. Its mission, in part, is dedicated to driving new innovations and collaborations to streamline the logistics infrastructure and operations. Luxembourg currently ranks second in the world for best performance in logistics according to the World Bank's logistics performance index.[64] Luxembourg's highly advanced logistics infrastructure and operations will enable the country to speed its transition into an automated, digitalized, and soon driverless transportation and logistics hub.

The erection of the automated Transportation and Logistics Internet will also have to transform the very way people living and working in Luxembourg view mobility. According to Eurostat, with 672 passenger cars per 1,000 inhabitants, Luxembourg has the highest number of vehicles per capita in Europe, while the average across the EU is 486 passenger cars per 1,000 inhabitants in 2013. Traffic congestion is compounded by a daily influx of workers from France, Germany, and Belgium. More than 175,000 commuters travel into Luxembourg daily, and 86% of them travel by car. Approximately 75% of the oil products sold in Luxembourg are consumed outside of the country. Luxembourg offers the most lightly taxed fuel in Europe, resulting in "gas pump tourism." With transport accounting for 64% of global warming emissions in

[64] See: http://lpi.worldbank.org/international/global

Luxembourg, the country has put a high priority on developing new, more sustainable, and less-polluting transport. The implementation of the governmental MoDu strategy will reorganize public transport and offer faster and more comfortable connections via a combination of train, tram, and bus lines. In 2013, the government of Luxembourg announced the goal of having 1,600 public charging points by 2020. Luxembourg City has also established bike sharing services available to individuals. The initiative is called "Vel'oH" and it includes 75 bike stations with over 700 bikes that are increasingly being used to mitigate automobile traffic and congestion on the streets.

Today's youth are using mobile communication technology and GPS guidance on an incipient automated Transportation and Logistics Internet to connect with willing drivers in car sharing services. An increasing number of young people prefer "access to mobility" over ownership of vehicles. In 2015, Luxembourg City unveiled its new car sharing service called "Carloh." While still in the pilot stage, plans call for a vast expansion in car sharing services. Future generations will likely never own vehicles again in a smart automated mobility era. For every vehicle shared, however, up to 15 vehicles are eliminated from production.

There are currently 1.2 billion cars, buses, and trucks crawling along in traffic in dense urban areas around the world.[65] Gasoline-powered internal combustion vehicles were the centerpiece of the Second Industrial Revolution. The mass production of these vehicles devoured vast amounts of the Earth's natural resources. Cars, buses, and trucks also burn massive amounts of oil and are a major contributor to global warming gas emissions, after buildings and beef production and related agricultural production practices. Larry Burns – the former Vice President of General Motors, and now a professor at the University of Michigan – did a study of mobility patterns. The results suggest that 80% of the vehicles currently on the road can be eliminated with widespread adoption of car sharing services over the course of the next generation.[66] The remaining 240 million vehicles will be, in great part, electric and fuel cell transport, powered by near zero marginal cost renewable energy. Those shared vehicles, in turn, will be automated and running on automated smart road systems. The trio of innovations in transport – vehicle sharing, electrification, and automation – will reinforce one another, and allow Luxembourg to reach a much more efficient and sustainable mobility system than what is prevalent today.

The long-term transition from ownership of vehicles to access to mobility in driverless vehicles on smart road systems will fundamentally alter the business model for the transportation industry. While the big auto manufacturers around the world will produce fewer vehicles over

[65] See: http://www.navigantresearch.com/research/transportation-forecast-light-duty-vehicles
[66] See : http://sustainablemobility.ei.columbia.edu/files/2012/12/Transforming-Personal-Mobility-Jan-27-20132.pdf

the course of the next 30 years, they will likely increasingly reposition themselves as aggregators of the global automated Transportation and Logistics Internet, managing mobility services and logistics.

The convergence of the Communication Internet, Renewable Energy Internet, and automated Transportation and Logistics Internet in an operating kernel becomes the global brain for an Internet of Things cognitive infrastructure. This new digital platform will fundamentally change the way people living and working in Luxembourg manage, power, and move economic activity across the numerous value chains and networks that make up their economy. The digitalized Internet of Things platform is the core of the Third Industrial Revolution.

STATE OF PLAY AND LUXEMBOURG VISION

Luxembourg, as a small country located between Belgium, France and Germany, is located at the heart of an integrated cross-border region. This strategic position allows the nation to have good connections with European road, rail, water, and air networks and to stand as an important point of intersection and interaction between passengers and logistics flows.

The country's projected strong economic and population growth (according to Eurostat,[67] population is expected to exceed 1 million in 2050) contributes to increased transportation and mobility, both playing a key role in the daily life of the national economy and society.

Policies and interventions need to be reviewed or identified in order to reach the targets defined in the Europe 2020 strategy, which requires Luxembourg to initiate far more aggressive efforts towards reducing greenhouse gas emissions and generating more renewable energy.[68]

A mobility challenge

The Luxembourg government has identified issues that mobility will face in the future and, in 2012, published a plan for a sustainable mobility called MoDu ("Mobilité Durable," Sustainable Mobility),[69] providing a set of objectives for the foreseeable future.

According to the MoDu, 2009 mobility modal share is composed of 72.5% motorized individual vehicles, 14.5% *transport en commun*[70] and 13% active mobility.

[67] Eurostat (2013), European Population Projections EUROPOP 2013
[68] See : http://ec.europa.eu/europe2020/pdf/csr2016/cr2016_luxembourg_en.pdf
[69] Ministère du Development Durable et des Infrastructures (2012) MoDu: Stratégie globale pour une mobilité durable pour les résidents et les frontaliers.

Despite the small population and size of the country, Luxembourg has the highest number of cars per capita in Europe (0.672, while the average is 0.486),[71] in constant growth (factor of 29 over 60 years), with an average CO2 emission of 147 g/km despite low average vehicle age.[72] Of existing passenger cars, 60% run on diesel and 40% run on petrol[73] – in which the rate of new diesel cars bought is 72%.[74] GHG emissions from Luxembourg transports reaches 7.6 million tons C02 equivalent vs. total Lux 11.8Mt, i.e. 64%.

The high number of cars, commuters, and transit traffic accounts for 54% of the country's energy consumption based on fuel sold (compared to 26% in the EU28), which has a significant impact on health and quality of life in public spaces. Furthermore, final transport energy consumption (road, railway and air amount to 2.5Mtoe) is 250% more than household final energy consumption (1Mtoe), making total transport energy consumption equal to 61% of Luxembourg's total energy consumption.[75]

Additional passenger car traffic comes from the 175,000 commuters per day representing, in absolute terms, the second highest number of cross-border commutes in the EEA. Among commuters, 40% work in Luxembourg City and enter the Grand-Duchy mostly via car (86%), train (9%), and bus (5%). The average daily commute of 90km takes 100 min. The cross-border phenomenon is mainly caused by the attractiveness of the Luxembourg economy which offers twice the number of working positions compared to the resident working population. As a cross-border region with low fuel prices, 75% of the fuel sold in the country is used by Luxembourgers, cross-border workers, transit trucks, and tourists.

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[70] The French expression "*transport en commun*" refers to all transport systems that imply a "common" use of the mobility resources, compared to a "private" one. A broader definition of "*Transport en commun"* includes the traditional public transport and all non-conventional transport systems such as on-demand personal and group transit systems, micro-mobility, shared vehicles and shared rides.

[71] European Commission (2015), EU Transport in figures. Statistical Pocketbook 2015. Available at: http://ec.europa.eu/transport/facts-fundings/statistics/doc/2015/pocketbook2015.pdf , p.84

[72] Eurostat (2015) Energy, transport and environment indicators. Available at: http://ec.europa.eu/eurostat/documents/3217494/7052812/KS-DK-15-001-EN-N.pdf/eb9dc93d-8abe-4049-a901-1c7958005f5b, p.96

[73] Eurostat (2015) Energy, transport and environment indicators. Available at: http://ec.europa.eu/eurostat/documents/3217494/7052812/KS-DK-15-001-EN-N.pdf/eb9dc93d-8abe-4049-a901-1c7958005f5b , p.94

[74] The International Council on Clean Transportation (ICCT) (2015) European Vehicle Market Statisticks. Pocketbook 2015/2016. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_EU-pocketbook_2015.pdf p.80

[75] European Commission (2015) EU Transport in Figures. Statistical Pocketbook 2015. Available at : http://ec.europa.eu/transport/facts-fundings/statistics/doc/2015/pocketbook2015.pdf , p.118

Latest data show that there are 275 kilometers of rail lines in Luxembourg (140km of double and 135km of single track).[76] The state road network consists of 2,908km of roadways (161km of highways, 837km of national roads, and 1,891km of paths used). Recent years have seen the saturation of existing road, parking, railway, and highway infrastructures, resulting in Luxembourg being the fourth most congested country in the EU.[77]

As already stated, public transport usage is low (14.5%) compared to the usage of individual cars (72.5 %) and active transport (13%). This car dependency is mainly driven by the following factors: urban sprawl, lack of mixed-used urban developments, the centralization of economic life, long travel times for public transport connections to rural and cross-borders areas, lack of efficient national regulations fostering the use of clean transportation means, lack of coherent cycle networks, as well as a strong car ownership culture.

Nevertheless, studies show the advantage in urban centers of active mobility rather than motorized vehicles. For trips between 1km and 3km, the bicycle is the fastest mode of transportation (even on uphill topography thanks to electric bikes). Urban travel speed for pedestrians and cyclists is, for the first 500m, higher than the speed of cars with an average speed of 4km/h.[78] This is interesting for Luxembourg, where 40% of daily trips represent less than 3 km. However, Luxembourg holds the European record for private car use, with 60% of trips below 1km.[79]

Furthermore, to incentivize more public transportation and alternatives to automobiles, the Transport Community (Verkéiersverbond) is setting up a telematics systems ("mLive") which will regroup the real-time departure times of the different public transport operators.[80] Real-time data is already available for AVL, TICE and CFL and, by the end of 2017, will be available for all the RGTR bus lines. Access to real-time datasets is provided by applications via an openly licensed API in order to make the integration of the RT travel time possible.

Finally, conventional transportation modes caused several negative externalities, with major consequences for safety and air quality.

Despite having implemented all safety regulations according to EU standards (drink-drive, helmet, seat-belt, child restraint, mobile phone use while driving and drug-driving

[76] EU Transport, 2015 Pocketbook, p.76 and 2014, p.46 and 55 / latest information from MDDI
[77] (INRIX, 2015)
[78] MoDu, p.145
[79] MoDu, p.22
[80] MoDu, p.159

law),[81]Luxembourg counted 45 road fatalities in 2013,[82] making it the 6th worst-ranked country in the European Union.

Transportation has a significant impact on air quality. Transport impacts on the atmosphere are twofold:

- Locally, for human health (due to CO, HC, NOx and PMs emissions)
- Globally, causing global warming and acid rain (CO2, CFCs)

According to the European Environment Agency,[83] premature deaths attributable to PM25, 03 and NO2 exposure are, respectively, 250, 10 and 60.

Investments and Initiatives

The Luxembourg government, during the totality of its parliamentary term, will have invested 2.4 billion euros in infrastructure[84] and launched the implementation of several MoDu elements to improve mobility and transportation in the country. The initiatives, led by government or municipalities, include a strong improvement in public transport, the LuxTram connecting the whole city, and the creation of multimodal hubs, new train stations in the outskirts of the capital, a reorganization of the regional bus network, car sharing initiatives such as CARLOH in Luxembourg City, plug-in hybrid electric buses, a new tax legislation favoring zero emission cars for private use and low emission vehicles until 2020, a national telematics project “mLive” for public transport, installation of 1,600 public charging points for electric vehicles until 2020, an additional 13,100 Park&Ride (P+R) parking spaces, and the creation of 700 km of additional cycling paths.

[81] World Health Organization, http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/,
[82] EC, p.102
[83] 2015, p.44
[84] L’essentiel (2015) “Faire davantage pour la mobilité ». Available at: http://www.lessentiel.lu/fr/news/luxembourg/story/17810484

LuxTram (source: site luxtram.lu)

The financial cost of new infrastructure is often highlighted as a strong barrier, yet the cost of inaction and negative externalities is often forgotten. Urban sprawl is extremely expensive because of necessary maintenance to roads and other infrastructure. The cost of traffic congestion is estimated to be 1 to 3% of a country's GDP. Lastly, the pollution impact on health as well as the impact of a widespread lack of physical activity are difficult to estimate in financial terms (see local and global impacts mentioned here above), but are too often neglected in the overall analysis.

Clusters fostering innovation

Luxembourg benefits from active national public research with strong ICT know-how and the best, most secure IT infrastructure (with excellent network coverage) in the world. This could lead to a significant potential in the deployment of Intelligent Transport Systems (ITS). Studies show that there is a high economic development potential for Luxembourg in this field and that while some companies are already active in the field, many more have the potential to enter that market. The University of Luxembourg and the public research center, LIST, do research on mobility solutions and related fields and have strong know-how in ICT.

The recent creation of dedicated clusters (automotive, logistics and ICT) also contributes to the dynamic development of some specific industries in these fields in Luxembourg.The Cluster for Logistics has united all institutional players and private enterprises in different competencies. Their shared goal is to strengthen Luxembourg's position as a major European logistics hub, especially for high value added services.[85]

[85] Clusters for Logistics Luxembourg asbl (2015) Luxembourg your multimodal gateway to Europe

The Logistics cluster provides a positive path toward a Third Industrial Revolution mobility paradigm by establishing the groundwork for the creation of a collaborative network and a common shared logistical space (fourth pillar of the Mobility Internet).

Luxairport (where market leaders such as LuxairCargo and CargoLux are based), the Eurohub South (where CFL Multimodal, a national player acting globally is based) the inland Port of Mertert (Luxport), and state of the art road and rail infrastructure provide Luxembourg with the necessary assets to be a leader in multimodal freight transportation.

Luxembourg is ranked second globally for logistics performance and is first for international shipments and timeliness.Additionally, the Grand-Duchy is well positioned in main areas of R&D. The government supports R&D projects with grants and has established a special program to promote joint research that encourages companies to collaborate with each other or with public research organizations.

Finally, further opportunities could derive from the innovation and implementation of automated vehicles and drones. In fact, according to a European Commission report, 63% of Luxembourgish people believe drones to be an efficient way to transport and deliver goods (vs. EU average of 57%). On the other hand, based on the Declaration of Amsterdam, pledged by all important mobility players and EU Member States, improvements need to be achieved concerning the “uncomfortable” perception that nationals have towards AV (65% compared to 61% at EU level).

In conclusion, with one of the highest GDP per capita in the world and the lowest debts and deficits in the EU, Luxembourg’s social stability ensures that the coalition government defines policies fostering a stable business and friendly environment to invest in an ambitious seamless and sustainable mobility plan.

Vision

An intelligent, sustainable, cohesive, and resilient mobility and transport ecosystem for the benefits of the Luxembourg society and economy.

The Luxembourg current mobility and transportation model based on the Second Industrial Revolution proves itself unsustainable, producing massive negative externalities and reaching its limits. With transportation accounting for 61% of energy consumption (and 64% of CO2 emissions), the transformation of this sector and the development of a new mobility paradigm is critical to the build-out of a new sustainable economic model in the country.

With the forecasted fast-paced rise of its population (above 1 million inhabitants predicted in 2050 plus some 320,000 cross-border commuters expected), Luxembourg will have to provide solutions for the projected increased mobility and transport needs. Incremental measures will not be sufficient to tackle this issue, the symptoms of which we can already witness: traffic congestion, pollution, loss in productivity, impact on quality of life, etc. A change in paradigm is necessary, implying fundamental disruptive transformations. Rising new technologies combined with greener energies and the build-out of a favorable mobility ecosystem will be decisive to revolutionize the Luxembourg mobility and transportation system. This approach implies the conjunction of several aspects.

Fast development of clean mobility based on e-vehicles and active mobility is a key priority to meet drastic reduction of emissions. By 2050, the vision is that Luxembourg will have a 100% electric fleet for passenger cars and public transport. Pending the availability of vehicles from car manufacturers, this would require specific measures and regulations that all new passenger cars and public transport be 100% electric from 2025 onwards.

However, while switching the fleet to electric cars addresses emission issues, it does not solve the problem of accessibility and traffic congestion. Therefore, E-mobility needs to be paired with policies of car sharing and car pooling and with automation technologies that will help respond to travel demands, in a much more flexible and multimodal way. Such a system, based on a performant and comprehensive transportation data structure, will enable the deployment of on-demand automated personal and group transit vehicles. This flexible transport mode is expected to gain a substantial portion of traffic in the next 10-20 years, thus redefining transport and freeing attractive space for active mobility in urban centers.

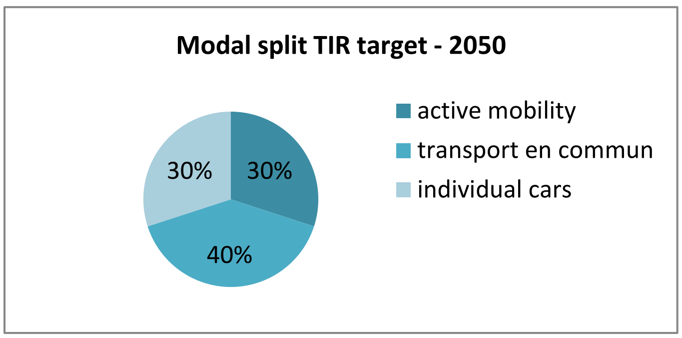
Automated Vehicles, along with the Communication Internet and the Energy Internet, constitute the kernel of the IoT platform. Automation technologies and the development of a resilient transport data system will be a strong source of efficiency gains for logistics through optimized travel of standardized goods, reverse logistics and last-mile delivery.

A *rich multimodal matrix*, including car sharing, car pooling, bicycles and other public transport systems – where mobility is seen as a service – is a key component of a shift towards sustainable mobility. All the transport solutions have to be integrated via a comprehensive data system to produce and deliver *a service* to support logistics needs and the individuals' daily routines.

Considering the forecasted population and commuter growth resulting from an extrapolation of current trends through 2050, the workforce will potentially increase to 755,000 people compared to 415,000 today.

	Working Force		
Year	Luxembourg	Commuters	Total
2016	240,000	175,000	415,000
2050	435,000	320,000	755,000

A significant shift in the modal split is targeted (in share of daily trips): 30% of active mobility, 40% of *transport en commun* (public and shared transport), and 30% of individual cars.



The table below shows the number of home-work trips in 2050 computed (a) assuming that the current modal split will be unchanged and (b) assuming that the target modal split will be reached.

	2016			2050 (current modal split)			2050 (target modal split)		
	Lux	Comm.	Total	Lux	Comm.	Total	Lux	Comm.	Total
Private Car	175,000	151,000	326,000	319,000	274,000	593,000	131,000	138,000	269,000
Public and shared transport	33,600	24,500	58,300	61,200	44,600	106,000	187,000	183,000	370,000
Active Mobility	31,200	0	31,200	56,800	0	56,800	131,000	0	131,000

In the 2050 scenario, where the travelling population is expected to rise by 85%, the target scenario in the modal split implies a reduction of individual cars by 18%, an increase of public and shared transport by over six times, and an increase in active mobility by four times.

These ambitious targets for public and shared transport and active modes need to be supported by a set of *push measures* oriented towards keeping people away from their cars. If public policy continues to favor improving the traditional road system, it could deter commuters from taking public transport. The pressures brought on by the demographic growth projections, low excise duties on fuels, convenient fiscal treatment of company cars and the increasing housing prices (doubled from 2000 to 2014) cause a rise in the number of commuters coming in from neighboring countries, all contribute to remaining locked into an old transport mindset that is becoming ecologically unsustainable (unless the target shift toward clean mobility is achieved) and increasingly untenable in terms of congestion.

A change in the transportation paradigm also changes the way people view mobility. In this holistic approach to mobility, a set of solutions is required which contributes to the build-out of a favorable mobility ecosystem in Luxembourg. Intelligent urban planning will be a critical priority in order to avoid private car dependency (urban sprawl, single use neighborhoods, and monopolization of public spaces). New flexible working schemes will also play a decisive role.

The new concept of *Mobility-as-a-Service* requires a 'cultural change' and specific supporting interventions in order to reduce what is called the "cost of cognitive effort" in changing behavior.

Knowing that the "high powered car" ownership culture is very present in the country, with the highest number of car per capita and high emission vehicles, encouraging new usages supposes a change of culture that can only operate through the emergence of a new narrative.

Finally, the creation of a sustainable mobility fund will help accelerate the transition by fostering innovation and developing a "mobility of the future" Luxembourg economy.

Going forward, Luxembourg will be an important testbed for smart mobility by building on its central location, its excellent ICT infrastructure and know-how, and the innovation driven automotive supplier sector. The recently launched inter-ministerial working group on "Smart Mobility" will help drive this innovation platform. The new Open Data Platform (http://data.public.lu) will provide open access to plenty of high quality mobility and non-mobility data to work with. Furthermore, the Automotive Components Cluster and its members represent a very innovative community and the new Automotive Campus that is being developed will allow well-established companies to work side by side with agile start-ups and resulting synergies between automotive and ICT will be exploited to the fullest. In the future, Luxembourg will offer companies ideal conditions through a nationwide network of intelligent infrastructures and services.

Resilience and the Transportation System for Luxembourg

The interventions identified in the TIR transport scenario will play an active role towards improving the economy and mitigating climate change. The challenge for transport planners and administrators is to ensure that the new mobility system, based on electricity from renewable sources, sharing, and automation, will guarantee high levels of accessibility and satisfaction of mobility needs, with an adequate level of service in terms of travel time, travel comfort, accessibility and reliability.At the same time, the transport system must be resilient to short and long-term disruption of services brought on by cybercrime, cyberterrorism, and extreme weather events.

The transportation system is one of the fundamental assets of a community: it is essential to allow people to reach workplaces, schools, and shops, to distribute goods, and provide services. Its malfunctioning may cause severe consequences in the resilience of the whole economic system (**city resilience**). In the case of extraordinary events, the transport system must be capable of returning to the previous existing **equilibrium** or be able to **change, adapt** and **transform** itself in response to qualitative stresses and strains that change the very nature of the society. The transport system must therefore have a high level of built-in resilience.

The resilience of a transportation system can be defined in different ways:

For the individual it means that each person has several alternative transport options to choose from, even under unexpected or catastrophic conditions, and in case their chosen option is not available any more (e.g. car breaks down, public transport is not available, person becomes disabled; personal income drops dramatically…)

For society it means that the transport system will guarantee the mobility of persons and goods even under unexpected conditions, in case a partial failure occurs to the transportation system (for example: unavailability of an infrastructure) or a complete failure occurs in a system which is complementary to the transport system (for example in the case of IoT: unavailability of electric power because of a catastrophic natural disaster or a cyber-attack).

Looking at the elements that make up the transportation system, failure may occur at four fundamental levels**: the strategic level** (long term economic, social and environmental goals); **the economic level** (assessment of the cost of the resources required for transportation) **the**

design level (infrastructures, vehicles and communication and information systems) and **the education level** (availability of persons with adequate skills to make the system function).

The TIR strategy proposes a radical change of the transportation systems of people and goods; ***the risks for the transport system in the TIR scenario, resides mainly in the lack of supply of electricity for charging vehicles and communication systems and in the collapse of the infrastructures components exposed to weather events, terrorism and cyber-attacks.***

So two questions arise:

- Is the proposed TIR strategy transport system more or less resilient than the current system?
- Is the proposed TIR strategy transport system proposed sufficiently resilient? And if not, how can it be made so?

The proposed TIR transport system will rely primarily on the same physical infrastructure of the existing transport system and will inherit its positive features that make it resilient: universality, to accommodate many different types of vehicles (diversity), offering multiple alternative modes and routes (redundancy); capacity to function even if partly damaged (robustness).

However, the TIR strategy for transport and mobility also proposes a number of fundamental changes in the current transportation system:

- **Total shift towards renewable resources:** Renewable energy is produced locally and mainly at small generation plants across the territory. This greatly increases local resilience since the region is protected against geo-political events that may jeopardize the supply of fossil fuels. It is also less likely that all small generation plants will fail, causing a catastrophic failure of the entire system. The electricity distribution system for transport can be made more resilient by making it redundant and self-fixing (robust).
- **Electrification of the powertrain of the vehicles:** The electrification of the vehicles, on the one hand, may increase the robustness of the distribution system, which does not rely on road-based tankers and shipments but, on the other hand, it will also make it less robust, since it cannot count on reservoirs. Liquid and gas fossil fuels, in fact, can be stored in large quantities, while electric energy is extremely difficult to store. Electric vehicles, having a much higher efficiency than fossil-fuel vehicles, are also more resilient against economic collapse. The system can be made more resilient by adopting a mixed strategy of power supply, comprising external supply, on-board batteries and, in the future, hydrogen fuel cells (diversity and redundancy).

- **Increase in the use of massive public transportation:** This policy can make the system of transportation significantly more resilient by better distributing the flows of passengers and goods over various modes of transport, by improving the security at stations and on board the vehicles (robustness), by implementing different types of interconnected but independent modes (train, tram, bus, shuttle etc., providing diversity) and connecting the major origin-destination pairs by different parallel modes (for example: bus and train, providing redundancy). The TIR public transport system is well diversified. It comprises buses (battery electric or hydrogen-fuel cells), trolley buses, trams, trains, automated shuttles and micro-mobility vehicles. Diversity is one of the keys for resilience

- **Promotion of "active modes":** Active modes are the most resilient modes of transportation. Walking and cycling do not require any supply of energy, connection to a grid, informative system, or costly infrastructure. A policy to promote walking and cycling and to provide a dense network of dedicated infrastructures, greatly improves the resilience of the mobility system, despite the limits of distance that are inherent with active transportation.

- **Increase in the use of shared vehicles and Mobility-as-a-Service (MaaS):** This has mixed effects on resilience. Anyone can have access to any vehicle in the sharing service, and not only to their own vehicle, thus increasing greatly the resilience of the system. But on the other hand, sharing and MaaS both rely on an information and communication system which may be prone to a complete failure in case of extreme conditions, making all the vehicles of the service unavailable. The network itself can be a target of a hacking attack. The system can be made more robust by increasing the redundancy and security against cyber-attacks of the communication and information system that regulate the availability of the vehicles. Diversity and redundancy can be increased by assigning the shared vehicle service to several independent operators, so that economic failure or cyber-attacks on one operator will not cause catastrophic failure of the system.

- **Increase in the use of automated, highly connected vehicles:** The increase in the share of highly automated and driverless vehicles will require that cars and buses be connected through V2V and V2I communication systems. A failure in the communication system may curb both the collective transport system and the individual transport system. Automation and communication is one area where a strategy to increase redundancy, robustness, and diversity is essential. The V2V and V2I communication networks that are essential for highly automated vehicles are at risk of being targeted by a cyber-attack. Automated vehicle systems also require a large number of highly skilled personnel. The system can be made more robust by allowing the possibility for a human driver to take manual control of an automated vehicle in case of failure, and for the vehicle to function in the absence of communication. Redundancy and diversity can be increased by allowing different communication protocols, acting together. Training the personnel locally is essential to making the system robust against lack of the adequate skills. The security of the communication networks is also of the utmost importance (robustness).

- **Change of the urban shape to a compact and dense model, with mixed-use neighborhoods:** The change of the urban shape is a long term proposition as the development of a city takes place on very long time frames. However, a compact city, with mixed use neighborhoods is the solution that best accommodates the reduction in the need to travel, while increasing the utility and effectiveness of active modes of travel. For these reasons, a compact and mixed city is by all means the city shape that allows for the most resilient transportation system. A resilient city will provide various alternative destinations (redundancy); different types of places to carry out daily activities (diversity) and the possibility to reach them even in the case of a catastrophic failure of the transport system (robustness).

PROPOSALS

Key Topics

The Third Industrial Revolution Internet of Things platform can help Luxembourg shift from a "fragmented, carbon intensive individual transport" to active mobility combined with renewable energy and multimodal transportation on a driverless road, rail, water, and air Mobility Internet, achieving the "vision for 2050."

The Mobility team, gathering various stakeholders of the transportation and mobility sector, has identified several key priority topics. The topics and proposals have been grouped into 4 main subjects that are considered relevant in the TIR scenario. These subjects are:

1. Shift towards emissions-free vehicles.
2. Shared transport in a multimodal environment.
3. Digitalization as an enabler.
4. Limiting/revisiting the need for mobility.

To effectively achieve the objective presented in the "Vision 2050," it is essential to embed the interventions in a broader systemic frame. With this in mind, Luxembourg will need to engage in six fundamental fields of action:

- **Infrastructure**: move away from heavy investments aimed at solving private car contingent problems and continue investing in infrastructures that change the way people move.
- **Technology**: boost the technological changes that will best increase the efficiency of mobility, in terms of energy use, as well as space occupation, safety and emissions.
- **Cultural shift**: actively promote the onset of a new cultural mindset that includes new mobility paradigms and new logistics expectations.
- **Pull + Push policy**: fiscality is one of the tools with which the authorities can leverage the behavior of persons towards a better mobility. Other policies, such as administrative and supply policies are particularly effective to shift behavior to sustainable mobility in the long run.
- **Urban planning**: urban planning and transport planning are so thoroughly entwined, that they should be considered but two faces of the same problem: how people stay in places, and how they move from place to place. In particular, planning of public spaces cannot leave active mobility aside.
- **Global policy:** no country is isolated and a small country like Luxembourg cannot plan in isolation from its neighboring countries, especially in regard to mobility. Luxemburg will need to reinforce the coordination of its actions with those of the neighboring EU countries, and at the same time, require that these countries acknowledge its plans and actions.

The specific transport strategies and measures consist of a mix that combines modern sustainable initiatives and innovative interventions. The proposals include a redefinition of the framework in terms of Mobility-as-a-Service. A *rich multimodal offer*, including car sharing, car pooling, cycling, walking and other public transports as well as innovative transport systems, all integrated via a comprehensive data system to produce and deliver *a service* to support and not to impinge on the individuals' daily plan of activities.

In the implementation of transport measures, it is important to account for the dynamic evolution of the system (i.e. how the demand will be distributed among the alternative modes available and how this will change over years). This dynamic evolution is something to be taken into consideration during the definition of the detailed plans.

The trio of innovations in transport and mobility – composed of electrification of the power source, automation of driving and wayfinding, and sharing of vehicles – is fundamental to reach the objectives of the Third Industrial Revolution in transport. The mobility system, as it is organized today, has a number of inefficiencies. One of its greatest inefficiencies is its massive reliance on fossil fuels, with enormous negative effects on energy waste, pollution and GHG emissions. Inefficiency also comes into play from relying heavily on privately owned individual vehicles, which travel nearly empty and spend over 90% of their time standing still, often occupying valuable space in crowded city centers. A further inefficiency comes from reliance on a human being for driving and wayfinding. Humans too often are not adequately informed, leading to poor decisions and errors. Last, but not least, unnecessary travel – a consequence of the car-centered Second Industrial Revolution social organization – represents another major source of inefficiency. These aspects of inefficient mobility will be dealt with in this chapter, and solutions will be proposed.

1 Shift Towards Emission-Free Vehicles

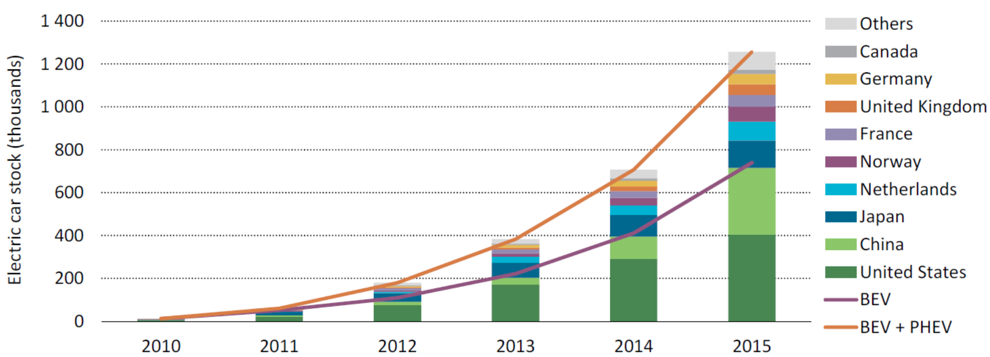
The current system for the mobility of persons and goods is almost totally reliant on fossil fuels, especially within urban areas. This reliance derives mainly from the abundant availability of fossil fuels as a relatively cheap and convenient energy source, the presence of a well-developed distribution network and the lack of truly competitive alternatives. The use of fossil fuel results in very low energy efficiency, not higher than 25%, and the production of high quantities of noxious pollutants, especially fine particulate matter and nitrogen oxides, as well as CO_2 and other greenhouse gases, not to mention noise.

Electric motors can achieve 3-4 times the energy efficiency of thermal motors, do not produce any local pollution or GHG emissions, and produce less noise. If they are powered by renewable, non-pollutant sources, pollution and GHG emissions can be eliminated completely. Even if the applied technologies are more expensive and less convenient than those associated with the use of fossil fuels, the global advantages of the electrification of mobility are so numerous that it justifies the shift to the new Third Industrial Revolution mobility.

Several trends are converging to ensure a speedy transition into a new mobility era:

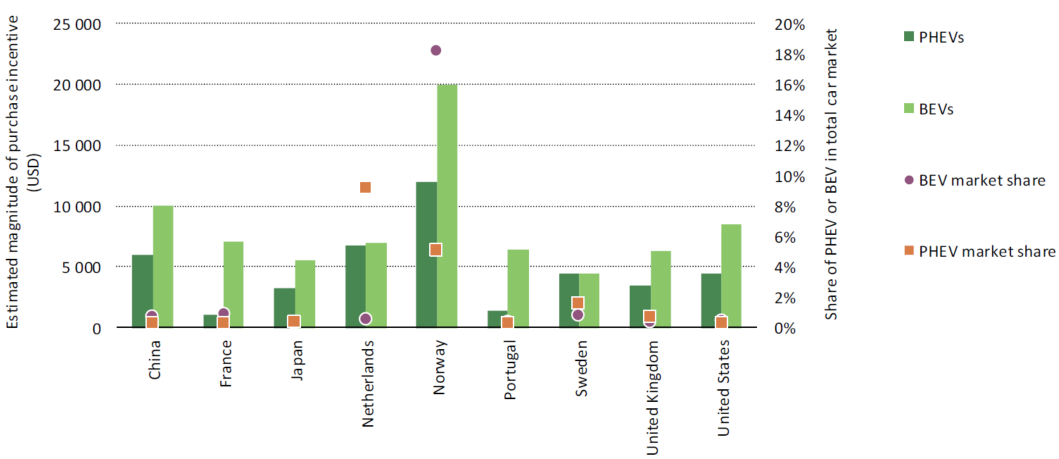
- The exponential decrease in fixed and marginal costs of renewable energies
- Other similar initiatives in Europe in favor of e-mobility (Norway, NL, France)
- The advantage of a small-sized country with short-distance commutes, favoring electric vehicles
- Increased access to solar PV energy (e-battery use)

A recent Bloomberg study on e-mobility calculates that in the mid-2020s, EVs will become cheaper in their total cost of ownership (TOC) than conventional vehicles.



Evolution of the global electric car stock, 2010-15

[Source: iea, Global EV Outlook 2016, page 4]



Purchase incentives and market shares for BEVs and PHEVs, 2015

[Source: iea, Global EV Outlook 2016, page 16]

Alongside with active mobility, the shift to electric is key in the transition towards clean mobility and moving transports to near zero marginal cost. Luxembourg should take its size and flexibility, as well as its strength in setting the regulatory framework rapidly as an advantage, and should promote the e-mobility technology. This includes electric passenger cars – both owned and shared, electric bikes, micro mobility, public transport as well as last-mile logistics. In order for the TIR vision to reach the goal of a 100% renewable energy fleet by 2050, it is recommended that all related new registrations in the country are electric from 2025 onwards. Overcoming the two main barriers to e-vehicles (EV) adoption – namely the strong purchase price gap versus conventional vehicles and range anxiety – will require further actions in Luxembourg in the long term.

1.1 Technical

When approaching the question of electric vehicles, it is key to establish a clear distinction between individual cars, public transport, and freight transport (last-mile, long and very long distances). Each of these aspects represents a different challenge. Deploying electric cars is the most challenging intervention, because of the number of vehicles and the infrastructure required. Trucks and public transport, in turn, pose a challenge because of the size and weight of the energy storage (batteries). The electric bikes (pedelecs) technology is the most mature and widely accepted by the public.

1.1.1 Battery vs. Hydrogen electric power supply.

There are two mainstream technologies today to store on-board and retrieve the energy required for electric traction: batteries and hydrogen gas coupled with fuel cells (HFC). Both technologies present advantages and disadvantages. However, the widespread availability of battery electric vehicles and charging stations compared to the marginal existing offer of highly priced hydrogen powered vehicles, as well as the lack refueling infrastructure and high production costs of hydrogen, all lead to a clear advantage of the battery stored solution in the short to mid-term.

1.1.2 Batteries as a power supply for electric vehicles.

Lithium Ion batteries are technically consolidated, relatively cheap, widely available, efficient, safe and reliable to use. The existing electricity distribution network can serve as a "fuel distribution network", without requiring building a wholly new network and removing most fuel tanker trucks from the streets.

Unfortunately, the energy density even of the best batteries is very low compared to that of fossil fuels: it takes on average 40-90 kg of Li-ion batteries to store the energy equivalent of one litre of diesel fuel. Even accounting for the higher efficiency of electric motors, in order to obtain a range of 500 km, a car would need to carry more than half a ton of batteries and a bus would need nearly three tons. Technological improvements in battery technologies can reduce costs and increase public acceptance of EVs. Price is predicted to reach slightly over 100 euros per kWh over the next 15 years, which is less than half of the cost today. New innovations for batteries in the form of larger capacity, less weight, and smaller size will contribute to the falling costs of battery technology. Although constant progress is being made in this area, the current state of the technology prevents the use of batteries in larger vehicles such as trucks and buses. Moreover, specific attention should be given to the sustainability of the batteries themselves.

In addition, batteries require a much longer recharging time than what is needed for the refueling of fossil fuel. This means not only a radical change of habit by users (no more casual refueling, but planned ones), but also the need for many more recharging points, located mainly at home, but also at parking lots and exchange stations. However, since the average daily distance travelled in Luxembourg by the majority doesn't exceed 60km, the range offered by most of the existing electric cars, (around 100-120km) is already sufficient.

At the same time, two major technological innovations will become mainstream: inductive and dynamic charging (charging without plug) and highly automated driving. With the combination of these two technologies, new EVs can charge themselves by driving autonomously to a free inductive charging point nearby. As soon as highly automated driving is established, inductive charging systems will be standardized and interoperable and these two technologies will become more and more affordable.

1.1.3 Hydrogen as a power supply for electric vehicles.

At present, hydrogen is a much less widespread technology for automotive use than batteries due to the disadvantages that were discussed in proposal 1.1.1 and therefore, at the moment, hydrogen vehicles have not yet been identified as an immediate priority. However, there are many advantages to hydrogen vehicles. On-board hydrogen tanks are only slightly heavier than fossil fuels tanks, and refueling is almost as quick. Hydrogen could replace fossil fuels, requiring only a slight change in driving habits by the users. Thanks to its high energy density, hydrogen could also be suitable in the long-run as a zero-emissions fuel for long distance trucks and buses.

Table 5
Relevant aspects of vehicle performance for battery-electric vehicles (BEV)
and hydrogen fuel-cell vehicles (FCV).
(Where appropriate, green = best, yellow = middle, and red = worst.)

Aspect	Current ICE	Battery electric (BEV)	Fuel cell (FCV)
Fuel type	Gasoline	Electricity	Hydrogen
Number of vehicle models available [7]	287	13	3
Average fuel economy [7]	23.3 mpg	105.2 mpge	58.5 mpge
Fuel economy range [7]	12 – 50 mpg	84 – 119 mpge	50 – 67 mpge
Effective cost per mile	$0.10	$0.04	$0.09
Well-to-wheels GHG emissions (g/mi) [8]	356 – 409	214	260 – 364
Well-to-wheels total petroleum usage (Btu/mi) [8]	3791 – 4359	54	27 – 67
Driving range (average) [7]	418 mi	110 mi	289 mi
Driving range (min – max) [7]	348 – 680 mi	62 – 257 mi	265 – 312 mi
Time to refuel	~ 5 min	20 – 30 min (DC Level 2) 3.5 – 12 hr (AC Level 2)	5 – 30 min
High voltage	No	Yes	Yes
High pressure	No	No	Yes
Availability of qualified mechanics	Yes	Limited	Limited
Availability of qualified emergency responders	Yes	Yes	Limited
Vehicle maintenance issues [9]	-	Lower maintenance than gasoline; possible battery replacement required during vehicle lifetime	Lower maintenance than gasoline; high-pressure tanks may require inspection and maintenance

[7] Model year 2016 (EPA, 2015a).
[8] GREET 2015 release, using default settings for model year 2015 passenger cars (ANL, 2015).
[9] AFDC (2014).

Comparison of various parameters (Source: B. Schoettle and M. Sivak, University of Michigan 86)

1.1.4 External power supply for electric vehicles.

Electric public transport powered by an external source already exists in the form of trams and trolleybuses. Once the network is connected to wind and solar power sources, these modes of public transport immediately become zero-emissions and zero GHG mobility.

Although the technologies to power electric vehicles described above all have advantages, their features quite clearly show that they can be specialized for different types of vehicles:

1- Battery electric power for personal cars, micromobility vehicles, city busses, short distance trucks, e-bikes and e-scooters;
2- Hydrogen coupled with fuel cells for long distance freight vehicles; not priotized at the national level, this technology should be considered at the regional or European level; Long-distance logistics, below 1000km, the needs of which are not satisfactorily met by rail solutions, could benefit from strong cooperation with neighboring countries on alternative fuel based solutions (“Future transport fuel” platform. Cf. energy pillar), given that the key transit question cannot be solved only in the context of Luxembourg; A different approach is taken for very-long distance freight (above 1000km) for which rail presents sustainable and economic advantages;

[86] See: http://www.greencarcongress.com/2016/02/20160201-umtri.html

3- External power source (overhead wires or on-ground power taps) for public transport (trams and trolley busses) independently or as a complement to on-board power source.
4- Biodiesels also can play a role in aviation.

Given Luxembourg's small size and relatively short commute distances, electric personal vehicles will be a feasible choice for the residents, without the problem of insufficient range. Many commuters will also have access to recharging facilities in their homes, allowing for night recharging. Commuters who reside in different countries may encounter more difficulties in shifting from fossil fuel vehicles to battery electric vehicles, especially if the diffusion of recharging stations is not extended to neighboring countries.

1.2 Business Model Innovation (BMI)

1.2.1 A fast and smart charging infrastructure program

To address the range question, it is essential to install a ***dense network of smart bidirectional charging points*** and ***pre-equip any new building*** with charging facilities. Since battery electric vehicles require significant time to be recharged, the recharging points cannot be placed only along the routes like refueling stations, but must also be located at sharing stations, parking spots, in parking garages, and also in residential areas for night charging. Since one fast recharging point can serve only 1-2 vehicles per hour, compared with 10-20 at a fossil fuel station, their quantity must be accordingly higher.

The build out of charging stations will take some time and should begin with the densest urban areas, where the limitations of electric vehicles are less evident and their advantages more pronounced. It should be noted that Luxembourg recently outlined a plan to install 800 charging stations with two charging points each by 2020. The public charging infrastructure provided by these 1,600 charging points (3,7 - 22 kW) is a positive step in promoting electric mobility and reducing range anxiety. However, these public stations should be accompanied by the installation of stations in every new residential and commercial building complex. It is also key to drastically increase the number of reserved parking facilities with charging facilities as it will reduce range anxiety and represent an additional advantage for EV users.

In order to enable long distance trips with electric vehicles, fast charging infrastructure (> 50 kW) should also be installed on highways and Luxembourg should prepare for new dynamic and inductive charging technologies.

EV charging must be smart. This means avoiding a scenario with all EVs charging at the same time. The charging, communication and billing infrastructure must be further developed and established to enable and force smart charging.

1.3 Public Policy Measures

There is much uncertainty in the time needed to obtain a substantial uptake of EV. So far, with the exception of electric bikes, EVs have faced extreme difficulties in developing into a mass marketed product, and all past predictions of future demand have forecasted a faster market penetration than what has occurred. The price of the vehicle, the short travel range, a dearth of recharging stations, and consumer skepticism (see for example results from the recent European *Green eMotion Project)* have all led to slow EV penetration of the market.[87]

A number of paths are available to win over consumers to the new EV mode of transportation, including:

- Providing the right information about how EVs work and contrast the spread of negative information, especially when not accurate (such as the famous "range anxiety").
- Allowing individuals to make their own experience, building trial programs where citizens can test the EVs for a given period.
- Building specific programs to help individuals understand to what extent their daily routine will change due to the use of the EVs and how they can restructure their routine efficiently.
- Favoring leasing programs that reduce the risk of not being able to sell the used EV and allow individuals to make a less risky personal experience, eventually combined with a service to exchange with another ICE car for longer trips.
- Establishing an interdisciplinary taskforce of officials from government, the business community, and academia (including MEC, MDDI, DSO, ILR) to identify regulatory proposals. Items for consideration should include standardized accessibility of charging points, new buildings pre-equipment obligations, energy sent back to the grid, and new revenue and business models, etc. Infrastructure needs should be a priority, and ***new legislation* should be considered,** allowing new vehicle registration only for emission-free vehicles from 2025 onwards.
- Ensuring sustainable electric batteries. For a truly sustainable EV developement, the entire environmental life cycle should be considered for electric batteries. Circularity should be encouraged as well as development of bio-based batteries through public-private partnerships. (cf. circular economy)

[87] See: http://www.greenemotion-project.eu/

- Establishing a “demand report” for public charging stations in urban and suburban areas for the next 10 years as a basis for EV infrastructure development within the country.
- Assuring the standardized accessibility of charging points by providing the necessary regulations. Access could be provided by NFC, Passports, credit card or by QR-code.
- Developing a roadmap on charging infrastructure along highways and promoting its implementation by regulation or incentives if needed.

Technical innovation will lead to the rise of e-mobility over the next five to ten years. The price of EVs will become increasingly reasonable, and even cheaper than that of conventional cars from mid-2020 onwards. Therefore, Luxembourg should take its size and flexibility as well as its strength to quickly establish the regulatory framework to work in its favor.

1.4 Financial Measures

1.4.1 Subsidize the purchase price of EVs.

To ensure an EV purchase price at the same level of that of conventional cars from the mid-2020’s, aggressive incentivation is necessary to address the cost barrier in this early stage of EV development. During this transition period, a significant subsidy should be given until the purchase price for EV becomes competitive with fossil fuel powered cars.

In 2017, the government will introduce a tax refund of 5,000 euros for zero emissions cars (Battery electric and fuell cell hydrogen cars) and will also reevaluate taxation of company cars to favor the shift to zero and low emission vehicles. A different taxation based on emissions will be applicable for leasing cars and will take into account three main categories: 100% electric or fuel cell hydrogen vehicles, diesel and hybrid diesel, as well as petrol and compressed natural gas (CNG) engine.[88] Diesel vehicles will be penalized compared to electric or gasoline cars.

These new incentive measures introduced in 2017 will be a good starting point. However, a more drastic game-changing measure is recommended: an ambitious incentive scheme whereby EV purchase price does not exceed the price of traditional cars. In the short run, new fiscal instruments taxing polluting vehicles and incentivizing emission-free vehicles have to be put in place following the bonus-malus approach (fiscally neutral and polluter-pay principle). In order to avoid an export market based on subsidy arbitrage, it should be on the condition that the owner will not sell the car within a defined period or mileage. The incentive could be tied to investment in renewable energy systems within the country. Energy suppliers could offer “EV electricity” based on RES, and EV buyers could be bound to use it.

[88] See: www.reforme-fiscale.public.lu

Similar subsidies can also be extended to companies and to cross-border commuters, after deducting any similar benefit they may receive in the country of residence. Subsidies can include a reduction or elimination of purchase tax, vehicle tax, and/or a subsidy for the purchase. Consideration should also be given to a tax favoring emission-free vehicles. This system can be complemented by a per-usage tax.

1.4.2 Incentives for EV Infrastructure.

In general, subsidies for private charging infrastructure are not needed, but they could support and encourage smart grid readiness:

- An additional incentive of 500 euros could be provided for private charging points if they are “smart grid ready” and controllable by the grid operator. These charging points should be capable of reacting to price fluctuations and to Big Data coming from the energy management system of the house / company.
- An incentive could also be provided if a Photo Voltaic system is installed close to a charging point is powerful enough to at least meet the electricity demand of the EV.

1.5 Educational

1.5.1 Public Information campaign for EVs.

A public information campaign for EVs is planned for the beginning of 2017 when the new incentive program starts and the first stations of the public charging infrastructure are erected. The campaign should continue (with updates depending on the evolution of the market) until the goals are reached. The campaign should aim to eliminate misconceptions about EVs (i.e. majority of people do not need high range) and to show the positive aspects of e-mobility in terms of pollution avoidance, noise reduction, and health. A campaign should also be run to educate people on when and how to use intelligent recharging.

2 Shared Transport in a Multimodal Environment: the Rise of the Commons

One of the main phenomena that characterize the Sharing Economy in the Third Industrial Revolution is the rediscovery of the commons as a form of governance. The success of the commons resides in the fact that nobody knows how to administer a community better than its own members. The rise of the commons presents a great potential in the transport fields, notably in transport logistics which is the core of the economic system of a community.

Thanks to the Internet of Things platform, logistics operators are discovering the opportunity to abandon individual management of the logistics chain in favor of collaborative networks, a common standardization of the processes and protocols, and a common network of warehouses. The opportunities reside mainly in the significant improvements in transport efficiency, especially in terms of load factors, itineraries, inventory in warehouses, and unsold goods brought about by minimizing congestion across the logistics value chain.

The rise of the commons also includes the transport of passengers through the proliferation of vehicle sharing systems, where usage prevails over ownership. With an increase of the traveling population by 85% in Luxembourg by 2050 and an objective not to increase the number of individual cars in the country, it is necessary to pursue important investments in the "commons" solutions, where mobility is offered as a service on a usage basis, as opposed to a one-off selling of a vehicle that is owned. An enhanced multimodality, where car sharing and car pooling are highly promoted, is central to this seamless mobility equation.

New forms of Third Industrial Revolution mobility also bring back to life the public commons, with the rediscovery of the value of the streets and squares and, in general, of the public spaces and public things. During the last century, the public square deteriorated with the expansion of the road systems for private vehicles. The rebirth of a public transportation system not only reduces pollution and energy consumption, but also frees up more space for the expansion of pedestrian zones and proper cycling infrastructure.

2.1 Technical

2.1.1 Enhanced multimodality.

In the governmental mobility strategy (MoDu), an array of P+R sites and multimodal hubs (named in French "pôles d'échanges") has been established in order to guarantee modal interchange between personal cars and transit services. Bus lines services have been identified to convey transport demand to the railway from the nearest territory. Further, express bus lines have been identified in the corridors where rail services are not present. In Luxembourg City, a connected network scheme, based on radial and circular connections and the new tramway network, has been identified as an alternative to the current scheme based exclusively on radial connections. The success of these strategies strongly depends on several factors regarding both personal and group transit. The following technical actions are suggested:

- Offer a variety of mobility services in addition to connections to public transports. Car pooling, electric car, electric bike (including the new system "Bring your own battery" that will be soon promoted in Luxembourg) and bike sharing areas (especially in Luxembourg City) could be designed with charging stations that will be directly supplied by solar energy harvesting technologies on rooftops. Even if managed by different operators, all these services should appear to the user as being part of a single system, with integrated payment service, coordinated information system, same graphics and platform.

- Avoid single-function interchange stations designed exclusively for transport use. They should provide other services such as professional meeting facilities, parcel delivery lockers, and grocery delivery. These services will contribute to make the intermodal infrastructures a lively place and add value to the overall travel experience. A multifunctional interchange should also ensure personal safety and security with adapted surveillance.
- Provide a high quality pedestrian and cycling infrastructure: walking and cycling are a necessary complement of public transport. There is plenty of evidence that people are more willing to walk or cycle, even over longer distances, if the environment is safe, pleasant, direct and well-connected.[89]
- Development of ICT in order to realize informed travel, communicate the best travel solutions in real time, facilitate the interchanges, promote the use of shared systems, and increase the reliability of the system as a whole. As foreseen by the MoDu, multimodal hubs ("pôles d'échanges") will be built througout the country to facilitate the shift between the different modes of transportion (train, tram, bus, cycling, car sharing, etc.) by offering real-time traffic information, modern and clean facilites and additional services such as shops.

2.1.2 Implement multimodal last mile solutions.

It is difficult to act in a short time on the urban structure implementing a more balanced density and land use for the city. With this in mind, it will be important to continue to implement a flexible and modern transport system (last mile solution) able to increment the capillarity of the public transport and bring the citizens near to their final destination.

This system can be realized through the implementation of *personal transit* (public transport able to satisfy personal travel) that collects inhabitants of suburban and rural areas and transports them to specific intermodal points that are well-connected with the economic center

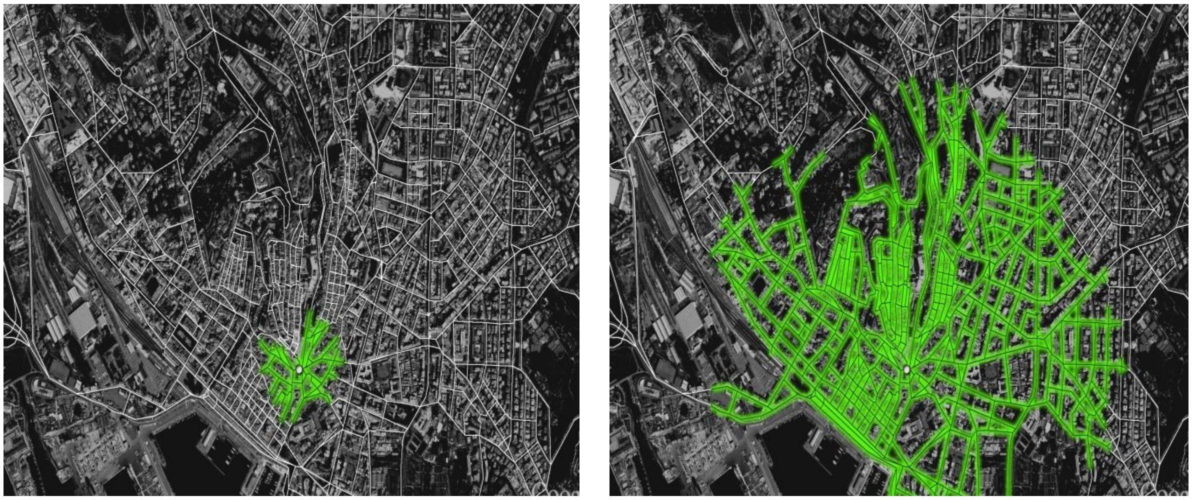
[89] There is ample consensus that quantity and length of pedestrian trips are very sensitive to the quality of the pedestrian environment. See for example Jan Gehl: "Life Between Buildings: using public space" Island Press 2011; Jarrett Walker: "human transit" Island press 2011; http://humantransit.org/2011/04/basics-walking-distance-to-transit.html; Jeff Speck: "walkable city" North Point press 2013.

by means of efficient, frequent and reliable mass public transport services (see section 3.1.3). Personal transit can also be achieved via good intermodal nodes that connect the mass public transport services with bike lanes, car sharing systems and so on.

Last mile systems can exploit transport automation technologies able to adapt the transport supply to the transport demand. These systems can also employ simpler shared compact electric vehicles that users can pick up and drop at station points distributed over the territory. To be efficient, this type of system requires a high development of ICT solutions for the management of the shared vehicles and the booking system.

Last mile systems must be able to satisfy personal travel and be ecological, sustainable and compatible with the urban fabric. This type of system can be realized using electric micro vehicles (e-quadricycles, e-scooters, and e-bikes) or traditional bikes that can be picked up at dedicated stations near to both the collective transport system and the final destination. This type of system allows travelers to reach destinations five times more distant from PT stops, than the ones reachable by walking.

Electric last-mile vehicle by Yamaha shown at ITS World Congress in Bordeaux, 2015



Area reachable in 5 minutes from a Public Transport Stop by foot (left) and using a last mile solution (right)

2.2 Public Policy

2.2.1 Pursue investments in Public Transport

Alongside with investment in active mobility, a well-designed and high quality public transport system is the best investment that can be made to save public space and reduce externalities:

1. Public transport is more "energy efficient" than the private automobile. Compared with a car transporting 1.3 passengers,[90] a 90-seat diesel bus with 23 passengers on board[28] uses 3-4 times less fuel per passenger km. This also results in 70-75% fewer CO2 emissions;
2. Public transport is more "space efficient" than a private automobile. A person riding a bus occupies, on average, 6-10 times less space than a person travelling in a private car.

Transferring a percentage of people from cars to buses, even adopting today's "dirty" technology, will achieve similar results in terms of CO2 reduction as will replacing the same percentage of fossil fuel cars with electric cars. Furthermore, buses allow a significant saving of urban space.

[90] Average value for Luxembourg, source Eurostat 2002.

The electrification of public transport must accompany the increase in supply of vehicles and routes in order to manage the increased demand. If public transport is totally electrified, and electric energy comes from renewable sources, the results can be striking. Under the same assumptions made above, compared to fossil fuel cars, buses will result in:

- A reduction of 80-90% of energy consumption;
- A reduction of 100% of GHG emissions;
- A reduction of 80-90% of urban space occupation.

Such values cannot be approached by a policy based solely on a shift to electric cars. Since the electrification of public transport will require significant investment and a long implementation time, hybrid vehicles offer an interim solution. The technology is available and very little infrastructural changes are needed. The RGTR already has a bus fleet of 21 hybrid buses and 12 plug-in hybrid buses will soon be added. The City of Luxembourg recently announced its plans to use plug-in hybrid busses and the City of Differdange plans to use four electric buses. Such efforts should continue to be pursued, as plug-in hybrid and full electric buses can significantly reduce both energy consumption and GHG emissions compared with diesel buses. Moreover, most models of these buses can travel for short distances in full-electric mode, eliminating pollution and reducing noise.

2.2.2 Pull Measures

Among the “pull” measures, special importance should be given to the promotion of public transport and active modes:

- Promote the image of public transport, treating the transport system as if it were a commercial product that needs to be sold. Marketing and promotion is highly valued for commercial products, but it is often undervalued when it comes to promoting “social” innovations. The public transport system should convey a sense of belonging, not only for those who use it, but also, and most of all, for those who don’t use it. It should be felt as part of being citizens of a city (in this case, a country); Public transport should project a precise and recognizable image of itself.
- Make public transport simple to use, recognizable and fully interconnected. Quality must be high and consistent throughout the services offered. Interchange between modes must be easy and convenient and walking to and from public transport must be planned as a part of the service, applying to it the same levels of quality, accessibility and ease of wayfinding that characterize the rest of the service. The nationwide introduction of real time departure data for all of the different public transport means by the end of 2017 (“mLive”) marks a further step towards seamless intermodal mobility.

- Provide commodities that allow users to make the most out of travel time: Wi-Fi internet connection in transport hubs, outlets to recharge mobile phones, availability of seating and of small tables, conveniance stores at major stations, etc. There is no reason why a bus or a tram should offer a worse quality of service than an airplane or a train.

2.2.3 Push Administrative policies.

This policy refers to a set of measures that coercively limits totally or partially non-sustainable transport means. Recommended measures in this line are:

- Banning polluting vehicles from entering certain parts of the city by designating marked off *Limited Traffic Zones* or *Pedestrian Zones*. This can be done permanently or at certain times; the ban can be imposed on all vehicles or on some categories, like ICE vehicles or pending emission level.
- Regulate parking by eliminating parking spaces along roads, provided that the liberated space will not be used to increase the car lanes but, rather, be reserved for bike lanes as well as bus lanes and space for pedestrians.

2.2.4 Push Supply policies.

Supply policies refer to interventions on the supply side, either vehicles or infrastructures. Among the supply policies that can be used as “push” measures, we recommend:

- Reducing the capacity of the streets – especially in urban contexts –, eliminating parking space along the road, and using some of the car lanes to build reserved bike lanes and/or reserved bus lanes. This is a key/strategic action to achieve the established goals.
- Re-distributing public space in a more “democratic” way. A person in a car occupies as much as 15 times the space of a person doing the same trip on public transport, and 35 times the space of a pedestrian. Space use in cities tends to reflect this inequality: more is allocated to cars, taking it away from other uses. Reserving lanes for public transport or walking can effectively increase the capacity of a street to carry people. It is of great importance that the available public space be redistributed equitably between public transport and active mobility to ensure the quality of service needed to convince people to change their habits.

It is important to note that limitations and prohibitions can be unpopular if not well-supported and justified. In particular, they have to be combined with new modes of mobility that are more attractive to users and more efficient to use. Social persuasion can help reach the objectives of a less wasteful system of mobility.

2.2.5 Multimodality

A strong multimodality is the keystone of the transformation of a traditional transit system into a modern, connected one where rail-based lines define a strong backbone system both at the national (railway) and city level (LuxTram). This reflects the vision of the government strategy (MoDu), which is currently being implemented: the tramway network in Luxembourg City, reorganization of bus lines at the national level, the multimodal hubs ("poles d'echange"), the increase of P+R facilities, and the reassessment of active mobility. This will make change of transportation modes more seamless and promote multimodality.

2.2.6 Promoting car sharing and car pooling

Car sharing and carpooling both have a strong potential to reduce traffic. For every car shared, 15 cars are eliminated from production and from the roadways. In addition, the shift from ownership of vehicles in markets to access to mobility in car sharing networks dramatically reduces both the fixed and marginal cost of mobility, making it a more attractive alternative for individual transportation. Car sharing is experiencing an exponential growth curve, especially among the millennial generation,[91] and demand is projected to increase five-fold by 2020.

Car sharing contributes to using parking space more efficiently, whereas car pooling aims to increase the number of people sitting in a car. Both modes have a high potential in Luxembourg of ensuring that the space allocated to individual transport is used more efficiently. The existing car sharing services in Luxembourg (for instance Carloh in Luxembourg City) have to be expanded in a way that offers a viable alternative to owning a car for residents or commuters.

The long-term potential of car sharing is intrinsically linked to automation technologies, where such a service will be ordered on a digital platform and driverless vehicles will provide door-to-door transport service.

2.2.7 Integrate Electric mobility with car sharing

Combining car sharing with electric vehicles will not only reduce the number of cars on the road, but also eliminate pollution and CO2 emissions, dramatically transforming the nature of mobility in Luxembourg.

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[91] Car sharing grew worldwide from 350,000 members in 2006 to 5 million in 2014 (the forecast that it will grow worldwide up to 26 million people in 2020 is then then realistic). On the other hand all forecasts of EV markets have been wrong.

2.2.8 Development of a collaborative platform in the logistics field.

Luxembourg is geographically positioned to play a key role in the establishment of an EU-wide digital, automated, and GPS-guided Transportation and Logistics Internet. To this end, Luxembourg can play a key role in helping create a collaborative network among operators in Luxembourg and neighboring countries to begin sharing a common logistics space (fourth pillar of the Mobility Internet) that could reach the ports of Belgium and the Netherlands, as well as the main logistic hubs in France and Germany. Cooperation can be implemented at two levels: Short-distance logistics collaboration (for city center delivery grouping) and Long-distance logistics collaboration for continental transport.

Attention should be placed on the separation of the International flows (88.2% of the total flow – Eurostat 2016) from the national and urban flows. The latter, in particular, require the implementation of a City Logistics process for optimizing the logistics and transport activities in urban areas in order to reduce the number of vehicles on the streets by using appropriate vehicles in terms of size and sustainable motorization (e.g. electric cargo-bikes), implementing reverse logistics, optimizing the load factor, and defining appropriate time bands available for the drop off and pick up operation outside the commuting hours.

Multimodality plays a central role in the development of a “transport-as-a-service” common platform. This concept stands as a turning point in the logistics field, where private vehicles and private management of logistics chains become increasingly abandoned for a multimodal flexible travel capacity and collaborative networks. Multimodality should be highly promoted, with the creation of the multimodal logistics platform in Bettembourg. Efficiency gains will also be achieved through optimized use of passenger transportation means. Such a flexible solution, hosted on a ***transports-as-a-service*** single-entry platform will be managed through collaborative networks with the prerequisite to unify regulations, standards and services.

2.3 Financial

2.3.1 Subsidize public transport modes.

Since the benefits stemming from sustainable mobility benefit the whole of society, the government should play a key role in incentivizing the transformation into a Third Industrial Revolution transportation and logistics network. The budget for subsidizing public transport services can be derived from fiscal policies addressed to tax the externalities produced by non-sustainable transport systems (space occupancy, pollutions, and GHG emission).

3 Digitalization as an Enabler

Investments in digitalization, smart infrastructures, and standard protocols of communication will facilitate the build out of the Internet of Things platform.

3.1 Technical

3.1.1 Build a comprehensive transportation data system.

A continuous flow of Big Data on transportation and logistics, made possible by the Internet of Things platform, will take Luxembourg into a new era of digitally mediated mobility. Vehicles in the network will be able to send and receive data in real time, communicating with other vehicles, the infrastructure, and buildings, allowing drivers and passengers to adapt journeys to real-time traffic conditions. Big Data will also facilitate mobile bookings, and optimize the scheduling of pick-up and delivery of goods. The increasing capacity to generate Big Data and mine it with analytics, creating algorithms and apps to increase aggregate efficiency and productivity is a radical change in mobility that will need to be carefully regulated. Resiliency will need to be built into the Mobility Internet to secure data and avoid cyberattacks.

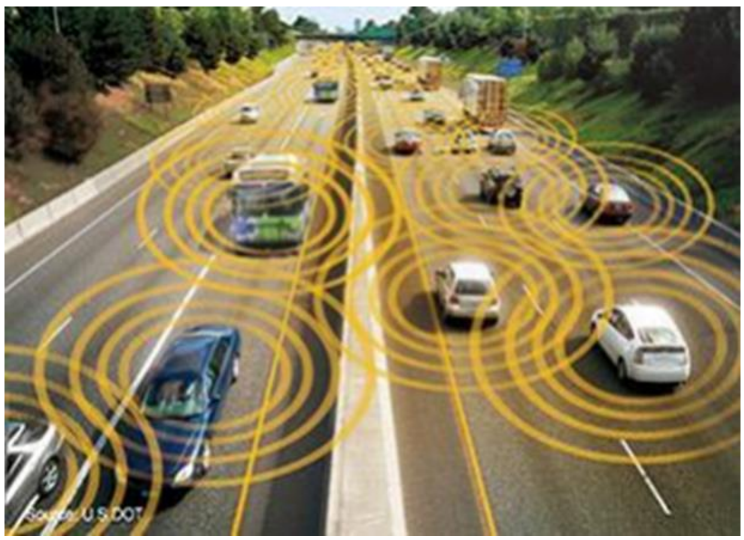
3.1.2 Boost autonomous cars

Autonomous personal cars, and taxis will take longer to appear than autonomous public transport, since they will have to be able to travel on any road, in any condition of traffic, with very little assistance from “intelligent infrastructure.” The first level of automation is introduced as “driving aids” in which the car is still controlled by a human driver. Today, some vehicles are technically capable of following a specified route, as well as making autonomous decisions such as changing lanes when overtaking another vehicle, or braking in an emergency. This is defined as “level 3” automation by the SAE. Full automation, not requiring the presence of a driver on board, is defined as “level 5” automation. The widespread availability of level 5 – fully autonomous vehicles – will likely be a reality after 2030.

Fully autonomous vehicles in an experimental context are already in play in Singapore and Pittsburgh. However, since these are experimental projects, a driver is still needed to supervise the vehicle and take control if needed. Companies like Google expect that in the next five to ten years, level 5 vehicles could be deployed. However, a scenario where most vehicles on the roads will be autonomous will likely take place after 2030.

All the preceding levels of automation will only remain driving aids where the presence of a driver is still needed and will not therefore have a substantial impact on how cars are used.

Only “level 5” has the potential to revolutionize daily mobility habits by substantially improving public transport and alternative means of transportation. On-demand bus or taxi services could be offered in areas and during times that are currently considered non viable. So far, the success of car sharing solutions relies on the proximity of nearby car sharing stations or free floating cars, whereas car pooling depends of drivers willing to make detours and share rides with others. Fully autonomous cars could bridge these shortcomings by focusing on the demand of the users.



Driverless vehicles are expected to improve traffic flow (Source: US Department of Transportation)

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver **monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Levels of automation as defined by SAE

3.1.3 Boost autonomous public transport

The automation of public transport is an essential component of the build out of an automated Transportation and Logistics Internet for the Grand Duchy of Luxembourg. Driverless public transport will reduce both the fixed and marginal costs of providing public transportation and helping expand services to low-demand areas and during off-peak times. This innovation marks the conjunction of electric, automated, connected and shared mobility.

Automated public transport is already technically viable and exists in select urban areas around the world. Given Luxembourg's dense commuter traffic, the country should be a first-adopter in introducing automated public transport across its transport corridors.

The launch of an autonomous public transport system (a.k.a. rapid Personal and Group Transit System), offering flexible on-demand and ultimately door-to-door mobility solutions is therefore highly recommended with pilot demonstrations in selected areas commencing as soon as the technology warrants.

Testing of fully autonomous, driverless shuttle buses in Bordeaux, 2015

Project - Launching an automated people mover system for group and personal transit

The true potential of AV lies in a shared e-AV system that can potentially redefine public transit connections. A recent study on Urban Mobility System Upgrades shows the potential impact of shared self-driving cars on city traffic. Depending on scenarios, the large-scale uptake of this kind of vehicle fleet could lead to a reduction of 8 to 9 out of every 10 cars in a mid-sized European City.[92] First-mover countries are already testing this technology, as illustrated recently by the joint venture between SMRT (Singapore) and 2Getthere to operate automated vehicle systems in the Asia Pacific region. Luxembourg should be a major player in the new transport system.

The automated system, operating like a horizontal elevator, brings a high level of flexibility to the transport sector. A specified network can combine on-demand personal rapid transit (up to 6 passengers), group rapid transit (shuttle for 20 to 25 passengers) and freight rapid transit. One of the major benefits of this technology is that it can address the need for on-demand transport and door-to-door services. To be consistent with the sustainable mobility strategy,

[92] See: http://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf

the fleets should be fully electric. According to the OECD study, in this scenario the impact on fleet size due to recharging time is minimal (+2% only).

Driverless transit system (Source: 2getthere)

Expected results are:

- Reduced number of individual vehicles in city centers (this system will contribute to increase share of public transport: a shift in modal split; public transport to reach 40% by 2050)
- Road safety expected to improve significantly
- A solution that can be optimized for last-mile delivery with a combination of passengers and goods transports (a flexible platform to develop urban reverse logistics through 2-flow optimization and packing stations)

3.1.4 Boost automated freight transport

Beside rail solutions, freight transport can also benefit significantly from automation, very likely earlier than personal cars. Moreover, freight vehicles tend to travel on specialized corridors, from fewer origins and to fewer destinations. This solution – that can be designed at the regional level – makes it easier to implement “equipped corridors” where freight vehicles can travel in platoons, or take advantage of a high level of automation, enhanced by efficient V2V and V2I communication. Within the loading-unloading areas, the freight vehicles can even shift from partial to total automation and maneuver on their own. Also this technological change, like for autonomous buses, is likely to occur, possibly within the next five years.

Daimler has already outfitted 300,000 of its trucks with sensors that are serving as mobile Big Data centers, monitoring traffic conditions, weather, warehouse availability, and other information in real time. Daimler is making the Big Data available to businesses, along with customized analytics, algorithms, and apps, allowing enterprises to continuously increase their aggregate efficiency and productivity while dramatically reducing their marginal cost and ecological footprint across their value chains. Daimler is among the prime movers in shifting their business model, in part, from merely selling trucks to also managing logistics on the emerging Mobility Internet.

3.1.5 Exploit the use of Drones

Drones will increasingly be used to deliver goods in the coming years. However, potential safety concerns will likely limit payloads to below 50 kg. The potential of drones should be fully explored and Luxembourg could be a testbed for drone technologies. A priority could be given to remote locations, before expanding their use.

Given Luxembourg's commanding presence in the satellite sector and its strong economic support to developing countries, new opportunities should be explored for utilizing drones in emergency relief missions.

Drones used for relief operations and last-mile delivery

3.2 Business Model Innovation

3.2.1 Redefining "Mobility as a Service'

Mobility as a Service is a new approach where each particular journey is offered as a service on a usage basis, as opposed to a one-off selling of a vehicle that is owned. This is strongly linked to the rise of the Sharing Economy, where access prevails over ownership.

Mobility-as-a-Service is made possible by combining and managing all transport services and trips on the same digitalized platform – starting as early as 2018. This unique gateway to mobility should be based on a robust real-time and predictive data management system able to provide users tailor-made transport solutions based on individual needs – with the objective of enabling users to enjoy a seamless on-demand travel experience.

The Mobility-as-a-Service digital platform will be set up in collaboration with all private and public transportation stakeholders and in cooperation with neighboring countries for a "Grande Region" approach that will eventually unify standardization, regulations, ticketing schemes, and booking services across the European Union.

The current *mobiliteit.lu* platform is limited to domestic bus, train, and pedestrian paths and does not yet include other mobility options. However, in 2014, the Verkéiersverbond introduced a new RFID public mobility card called the "mKaart." In addition to public transport tickets, the card is designed to give access to all other modes of mobility services. Secured bike parks – "mBox" – can already be accessed via the mKaart and beginning in 2017, the mKaart will also enable access to park and ride facilities and 1,600 charging points. This is a very good basis for a comprehensive platform.

Such a system is currently evolving with the *mobiliteit.lu* and will stand as a centerpiece of the Mobility Internet. Information provided will show all public transport solutions as well as P+R availability for private car transport, bikes and e-bikes availability, walking times, ride sharing options, booking services and road user charging, and dynamic pricing for parking, depending on peak / off-peak hours. In the long run, this could also serve as a platform where people can share their autonomous car and generate revenues. The single-entry system is a response to the multiplication of sharing platforms that are part and parcel of the new mobility solutions. It should be set up in cooperation with all private and public transportation stakeholders and with neighboring countries for a "Grande Region" approach that will eventually unify standardization, regulations, ticketing schemes, booking and services across the European Union.

For the Mobility-as-a-Service system to work properly, it is important that:

- A single travel document must be available for mobility throughout the region and for every mode of transportation.
- Information about all available transport means must be easier to access and understand.

Mobility-as-a-Service, a promising concept

3.2.2 Invest in automation

In the long run, automation leads to new revenues: driverless car owners will be able to share their vehicle on a single platform. This reduces the cost of car ownership since the vehicle is rented when not used by the owner.

Automated mobility can yield several advantages:

- Make traffic safer, reduce the risk of congestion and reduce the overall space occupied by cars, parked or in motion;
- Offer greater mobility and benefits for an aging population and disabled persons;
- Make public transport cheaper and more available. This means that public transport can become available also at low demand times, and in low demand areas, where traditional public transport is not convenient;
- Open up new scenarios for shared vehicles. Electric autonomous vehicles can reposition themselves and pick up new passengers, or autonomously reach a recharging point when needed. This is akin to a taxi service, but without taxi drivers;
- Create new job opportunities in the automotive, technology, telecommunication, and freight industry, thereby generating economic development.

3.2.3 Develop intelligent logistics chain.

To make an efficient transition, the Cluster for Logistic needs real time logistical data and traffic conditions provided by a strong ICT infrastructure and know-how (where Luxembourg is a leader in Europe) together with Connected Intelligent Transport Systems (C-ITS) made up of highly automated vehicles able to communicate with each other, with the infrastructure and buildings, as well as with operators. Real time communication provides the best vehicle choice and road path according to the traffic flows, request to shipment, load factor, and warehouse storage capacity.

3.3 Regulatory

3.3.1 Norms for automation

The practical implementation of autonomous vehicles is limited by the absence of laws that allow them to travel on public roads. Given adequate laws and regulations, it will be possible in the next ten years to extend this technology to larger and faster public transport vehicles, travelling on dedicated lanes, with some controlled interference with traffic (for example: crossings with activated traffic lights), and autonomous truck platooning in controlled environments.

The current scenario is characterized by a lack of adequate norms, but the recent Declaration of Amsterdam, signed by the EU Transport Ministers on 14 April 2016,[93] aims at removing the legislative barriers that today represent an obstacle to the roll out of vehicle automation.

Autonomous vehicles will require a significant amount of data to be exchanged: from vehicle to vehicle, from/to infrastructure, and in some cases, from the vehicle to the control center and vice-versa. The concerns are mainly liability, privacy of data, security against hacking, and robustness against transmission errors or gaps in the capacity of transmission channels.

However, this is not different from similar issues regarding wireless data transmission such as Wi-Fi transmission of sensitive data, mobile phone communication, and the communication of airplanes with land control centers. Protocols already exist that guarantee a high level of data privacy, security, and error control. These protocols need to be standardized and be made applicable across continental land masses.

[93] See: https://english.eu2016.nl/documents/publications/2016/04/14/declaration-of-amsterdam

3.4 Public Policy

3.4.1 Dedicated taskforce for AV's transition

Consideration should be given to the establishment of a dedicated taskforce to expedite the AV transition for Luxembourg.

The creation of a cluster for autonomous transportation will prepare the Grand Duchy for the advent of autonomous driverless vehicles. The dedicated taskforce "smart mobility," gathering public and private stakeholders (MEC, MDDI, R&D, LuxInnovation, Cluster for Logistics), will address various aspects of automation (cf. Smart economy pillar). In this context, the future Luxembourg Automotive Campus is a strong asset and will house research and innovation activities of several companies within the automotive sector.

The taskforce should focus on the following areas:

- Attract companies for testing of connected and automated driving technologies in cross-border corridors
- Conduct pilot studies on dedicated sites (e.g. Belval Automotive Campus)
- Explore regional truck platooning projects and drone technologies opportunities
- Cooperate with other countries (i.e. BeNeLux) on larger proof of concept
- Study the ethical issues around the automation of transport, including privacy, data security, open access, etc.

3.4.2 Implement a pilot test

The uptake of autonomous vehicles will require some transition time. The city authorities are key stakeholders in the transition to automated vehicles. Initially, a negotiation will be necessary to implement potential restrictions to normal traffic in order to set up experimental projects for automated vehicles on specific corridors.

3.4.3 Implement robust resiliency standards.

A robust resiliency monitoring program able to track traffic conditions for passengers and goods flows, the capacity of the infrastructure, and energy demands that can be used as a database to model prediction scenarios for massive disruptions to the system brought on by catastrophic climate change events and or cyber-crime and cyberterrorism should be provided.

Vulnerability assessments should be performed based on the traffic models to predict the effects of system components failures (infrastructures, energy supply, communications), taking into consideration the interdependencies between the various critical infrastructures and components. In the short-term, mid-term, and long-term transport plans should be updated based on the monitoring of the mobility matrix and vulnerability assessments, and identify the "resilience" strategies and measures needed to adapt to potentially catastrophic disruptions. Strategies and measures must be identified, in cooperation with key stakeholders, in Luxembourg and in collaboration with neighboring countries. New resiliency standards and operations will need to take into account not only the technical aspect but also the social and governance aspects of massive disruptions to the system.

3.5 Educational

3.5.1 Informative campaign for automated vehicles.

The issue of public awareness and acceptability is an important one. In the initial phase of the implementation, the personal or collective "discomfort" experienced by passengers towards riding in a driverless vehicle is often pointed out as a limit to the uptake and effectiveness of driverless technology. This is also evident in all surveys that address this matter: the majority of persons interviewed prefer to have an attendant on board, even if only with the role of "supervisor."[94] However, the convenience of the system can easily overcome this initial suspicion. Many autonomous transport systems are already operational all over the world: automated metros; automated people movers; Group Rapid Transit such as Morgantown and Rotterdam; and Personal Rapid Transit such as in Masdar City and Heathrow airport. These systems are widely accepted and used, and very little "discomfort" is felt among their current or potential users.

4 Limiting/revisiting the need for mobility

Luxembourg City comprises 40% of the Grand Duchy's employment, even though it only represents 18% of the population. Difficult and lengthy commutes are therefore a key concern, and companies are already finding it difficult to attract talent from neighboring countries because of traffic congestion during the commutes. Intelligent urban planning and transport planning that promotes dense and mixed use settlements is a critical priority. This new approach will promote active mobility and short distance travel between home and work.

The digital revolution and augmented and virtual reality environments will increasingly decouple work activity and the traditional working space (often the office). Telework and

[94] B. Shoettle, M. Sivak (2014) Public opinion about self-driving vehicles in China, India, Japan, the US, the UK and Australia; University of Michigan TRI.

remote working spaces will increasingly limit mobility demands in the future, and should be factored into future transport planning to prevent the underutilization of the transport system.

4.1 Technical

4.1.1 Transit oriented neighborhoods

Transit oriented neighborhoods should prioritize the following areas:

- Urbanization should be promoted along strong corridors and areas with the best public transport offer (cf "plan sectoriel transport");
- A coherent, safe and attractive network of dedicated cycle routes should be put in place covering the entire territory of the Grand-Duchy, with a particular focus on fast and comfortable cycling access to work places, schools, and transport hubs including train stations, tram stops and P+Rs. Cycling paths are currently a priority in Luxembourg. However, cycling is seen more as a leisure activity than a transport means. Fast cycling lanes should be straight and equipped with sensors that will prioritize bicycle over car users. As of today, cycling trips in Luxembourg are far fewer than car trips. But, with half the trips shorter than 5 kilometers, there is ample potential for improved cycling infrastructure at the local level, enabling the shift from motorized trips to cycling, especially at peak hours, when the average speed of individual cars is no higher than that of a bicycle. For car trips longer than 5km to be replaced by bicycle trips, comfortable and direct cycle routes, imposing as few stops as possible, are key.

Expected results of the prioritization of transit oriented neighborhoods are numerous: fast lanes will extend the range of bicycle trips, limit congestion on highways, reduce accidents, increase safety, reinforce multimodality, increase flexibility, promote healthy mobility and well-being, and ultimately increase productivity.

4.2 Business Model Innovation

4.2.1 Integrate transport policies, strategic regional planning, and Urban Policies

The intensive use of the private car in Luxembourg is attributable to many factors including Luxembourg's outmoded urban development plan (urban sprawl, trans-border commute) and the accompanying centralization of economic life. It is very difficult for a traditional public transport system to serve areas with low density of population living in detached housing neighborhoods (last mile problem). This is the main reason why a scattered territory generates car use dependency.

An integrated transport-land use policy must be planned in coordination with the implementation of transport solutions. This can only be achieved through closer cooperation between municipal and national authorities. The emphasis is on "an intelligent urban planning" as the centerpiece of a new mobility paradigm.

4.2.2 Telework

According to STATEC figures (2010), 7% of employees in Luxembourg work from home while 75% of employees have no flexibility. Teleworking can significantly reduce employee commutes. Some studies[95] show that in principle:

- a twice-a-week teleworker theoretically reduces commute trips by up to 40% for a typical 5-day a week worker;
- a telework program that reduces 10% of vehicle trips may reduce 15% of vehicle mileage if participants have longer than average commutes;
- neighborhood telework centers reduce commute vehicle miles travelled by about 50%;

This should be combined with attractive infrastructure for active mobility and emission-free vehicles between the home and the neighborhood's telework center, making automobile use superfluous.

However, telework does not always reduce total vehicle travel unless it is implemented in conjunction with other travel reduction strategies. The real impact is often much lower because people who telework are likely to substitute the travel to work with other non-work related travel (Rebound Effects). For Telework to provide significant vehicle travel reductions it must be implemented in conjunction with other travel demand *push and pull* strategies.

The following measures need to be pursued in order to develop Teleworking:

- Encourage flexibility with new adjustable working hours or days. In the case of Luxembourg, two forms of teleworking are suggested (to the extent possible):

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[95] Dennis Henderson and Patricia Mokhtarian (1996), "Impacts of Center-Based Telecommuting on Travel and Emissions: Analysis of the Puget Sound Demonstration Project," Transportation Research D, Vol. 1, No. 1, pp. 29-45.
Susan Handy, Gil Tal and Marlon G. Boarnet (2010), Draft Policy Brief on the Impacts of Telecommuting Based on a Review of the Empirical Literature, for Research on Impacts of Transportation and Land Use-Related Policies, California Air Resources Board (http://arb.ca.gov/cc/sb375/policies/policies.htm).

  - 1 day/week: no home to work trips (particularly important for Luxembourg commuters) leads to a potential reduction of traffic by 20%, which has a huge effect on traffic congestion and related negative externalities. Considering specific constraints for crossborder workers, a first step could be to reach this target for all Luxembourg residents with compatible functions and enclined to change their habits in the short-term. Discussion at the regional level should seek harmonization between neighbouring countries.
  - Telework during peak hours. Some employees can already adapt their starting and end time in-between predefined time slots. Further flexibility and especially the possibility to work at certain days directly from home should be allowed. While this solution avoids congestion, it does not reduce total travel.

- A dedicated taskforce should be created, with the aim of adopting new legislation on telework; its members will discuss various aspects such as fiscal and social benefits issues, data privacy, and flexibility with adjustable working hours or days.
- Develop co-working spaces in outskirt areas (close to borders as a first stage in Luxembourg to avoid current taxation and social protection barriers) and build adequate infrastructures that will allow for remote work, videoconferences, etc. (cf. the New World of Work). These new office spaces should be located near multimodal transports hubs for flexibility.
- Create a prototype in targeted areas with work spaces (from the municipalities or companies pooling) and subscription cards (per hour fees).

4.3 Regulatory

4.3.1 Integrate transport policies and Urban Policies

The shift to a digital Third Industrial Revolution mobility, transportation, and logistics infrastructure that is interconnected and highly efficient will need to be accompanied by a regulatory regime that enables all of the facets of mobility to operate together seamlessly. The regulatory regime needs to prioritize the following:

- Ensure easy access to public transports and develop transit options through multimodal infrastructures. Switching between transport modes should be effortless.
- Encourage active mobility through pedestrian pathways and bicycle lanes with connections to external cycling paths. Active mobility should also be encouraged through

the promotion of shared spaces (cf. shared space best practice in Bertrange) and car free areas in districts during specific hours and around dedicated spaces like schools as well as through the installation of parking spaces at the periphery of the district with a high share of parking slots reserved for EV or shared cars.

- Foster car sharing and pooling with dedicated facilities (drop-off areas, reserved parking slots).
- Encourage e-mobility through reserved parking slots and compulsory charging stations in all new urban projects with a strong focus on multimodal hubs.
- Prepare for shared AV deployment – traffic lanes reserved for public transport should be opened and adapted to automated group transit vehicles, if capacity is available.

4.4 Financial

4.4.1 Fiscal policies: Internalization of externalities.

The main external costs of transportation are: public health costs due to a lack of physical activity, space use, pollution, generation of GHG, accidents and depletion of non-renewable resources. Each of these can be taxed, and the revenues will replace the external costs, which are, by all means, wasted resources. The revenue from externality taxation can be used to improve the sustainable mobility system. This will provide clear and visible proof that the taxation serves the purpose of improving the mobility systems alternative to the private car. In particular, we suggest that:

- Space occupation can be taxed through parking fees and urban access fees.
- Pollution, GHG emissions and depletion of non-renewable resources can be taxed through a combined tax scheme: per-km car use fees, and taxation on fuel, taxation dependent on emissions.
- Accidents are more difficult to tax directly, since the taxation should address “risk” and not the actual occurrence of a crash. For this reason, the external cost of accidents is better addressed by regulatory measures. However, it must be clear that the cost of crashes is a high component of the external costs of mobility, and therefore, the “internalization of externalities” should be addressed in an operational plan.

In 2013, environmental taxes in Luxembourg amounted to 2.15% of GDP (the lowest since 2000) – below the average of EU-28 levels (EU, January 2016). The 92.6% of the total is represented by Energy taxes. The revenues from taxation of transport (excluding fuel) are low compared to other EU countries (0.15% of GDP compared to an average of 0.49% GDP). Following the recommendations from the OECD:

- An environmental fiscal reform is needed to reduce incentives for workers to reside far away from their workplace.
- Luxembourg should consider creating a Sustainable Mobility Fund that will facilitate the funding of sustainable transport initiatives. It would follow the internalization of externalities principle and would act as a three-fold financing tool:
    - Finance additional specific incentives targeted at users (managed by the Ministry of Finance)
    - Subsidize innovative municipalities on mobility developments (managed by the MDDI)
    - Contribute to financing start-ups and innovative projects including on-field pilot tests and experimentations as well as research and development works (managed by the MEC)
- In the phasing out period, where fuel tourism will still be important, it is recommended that a substantial part of fuel tax revenue be dedicated, on top of the Climate fund, to the specific financing of sustainable mobility projects. A percentage of the 2.7 billion liters sold revenue in Luxembourg could be directed to this Sustainable Mobility Fund. The sum allocated to this fund has to be considered, keeping in mind the cost of negative externalities which are estimated to be at least 1 to 3% of the country's GDP. Potential synergies will be sought with the Luxembourg Sustainable Development Finance Platform (cf. Finance). The Luxembourg Sustainable Mobility Fund could be created in the very short term.
- As stated above, new fiscal instruments taxing polluting vehicles and incentivizing emission-free vehicles have to be put in place in the short run, following the bonus-malus approach (fiscally neutral and polluter-pay principle).
- Circulation taxes are more directly linked to emissions. A per-usage tax, providing extra funding, represents a particularly efficient tool for taking into consideration the actual vehicle usage.

All these fees and taxes are extremely unpopular and pose economic planning problems. For example, higher fuel taxation will reduce or eliminate "fuel tourism," which is a source of traffic and externalities, but also a source of revenues for the country, representing about 75% of fuel sales in Luxembourg, and accounted for an earning of almost 1,500 euros per resident in 2008.

In saying that, we are aware that it is difficult for Luxembourg "to reform any tax unilaterally, as cross border impacts on the economy can be significant. Germany and France, which border Luxembourg, can absorb small changes which would significantly affect the Luxembourg economy in their considerably larger territories."[96]

Another important obstacle is that the high income level of Luxembourg makes the demand for cars less elastic to the costs. For this reason, we also recommend that further regulatory actions be taken in the form of"push" measures that limit the non-sustainable transport modes.

4.5 Educational

4.5.1 Encourage new usages and behaviors – the cultural shift.

A cultural shift is underway right now in all developed countries: car ownership is not a paramount objective for Millennials, and "high powered car" ownership is no longer a powerful status symbol as it was only ten years ago. This cultural shift will be pushed by new "symbols" which could come from IT technologies, and could be aided if the new transport solution and the technologies will be able to approach the levels of comfort, flexibility, reliability and security of the cars. All the transport systems and related technologies must always take into account the needs of the people. If alternatives to cars will be able to do that, we believe that a cultural shift will be easier.

Pursuing the vision of transitioning from a "traditional" carbon-intensive and inefficient transport system to a "Mobility Internet," combined with active mobility, is "revolutionary" and not just incremental, and requires an equally ambitious cultural shift to make it happen. It is important to stress that a change in cultural values means a change in individual preferences. The cultural shift should be promoted immediately and aggressively in order to match the speed of meaningful change brought on by vehicle sharing in driverless electric and fuel cell transport on an automated intermodal Mobility Internet. For example, a public education campaign should be launched around the benefits of sustainable modes of transportation in reducing environmental pollution and improving personal health, with a focus on the four main drivers in people's transport choice: speed, comfort, cost and safety.

[96] Study on Assessing the Environmental Fiscal Reform Potential for the EU, published 15 January 2016. Page 449.

Social security is also a consideration that must be taken into account. Today a car represents a comfortable and protected environment and is often not comparable to the situation at a bus station or cycle lane, especially during rush hours. Technologies able to guarantee personal security must be integrated alongside the new transport systems.

Multimodal journey calculators have to be put place in order to easily compare the real-time travel times, prices and costs of the different modes of transportation. This is planned for *mobiliteit.lu* for the beginning of 2018.

Importantly, companies play a central role as they can strongly encourage a shift in behavior: the aim should be to favor a mobility budget (as opposed to car benefits) as well as systematic company mobility plan, where key drivers in users' transportation choices can be addressed.

4.5.2 Implement easy demos

Communication programs and regulatory measures are critical to ensuring a transition to a Third Industrial Revolution mode of mobility. While this is important, we should also remember that even here there is a need to change individual habits, and this takes time. It is done by reinforcing positive user experience with the new forms of mobility.

Providing the transport system for free for a while is typically important, though empirical cases show that after the incentives are over, many people will go back to the old system. So it might not be enough. A push measure on the car, combined with the "pull" incentives, is crucial.

Encourage the young generation through reinforced mobility school programs and gamification for the teens. Many of the actions included in this plan will take a long time to be fully effective, and the people who today are in their teens will be the ones who can fully benefit from them. But they must start today to become aware of the need and the advantages of this transformation.

4.5.3 Lighthouse project - Deploying a mobility testing and demonstrating corridor.

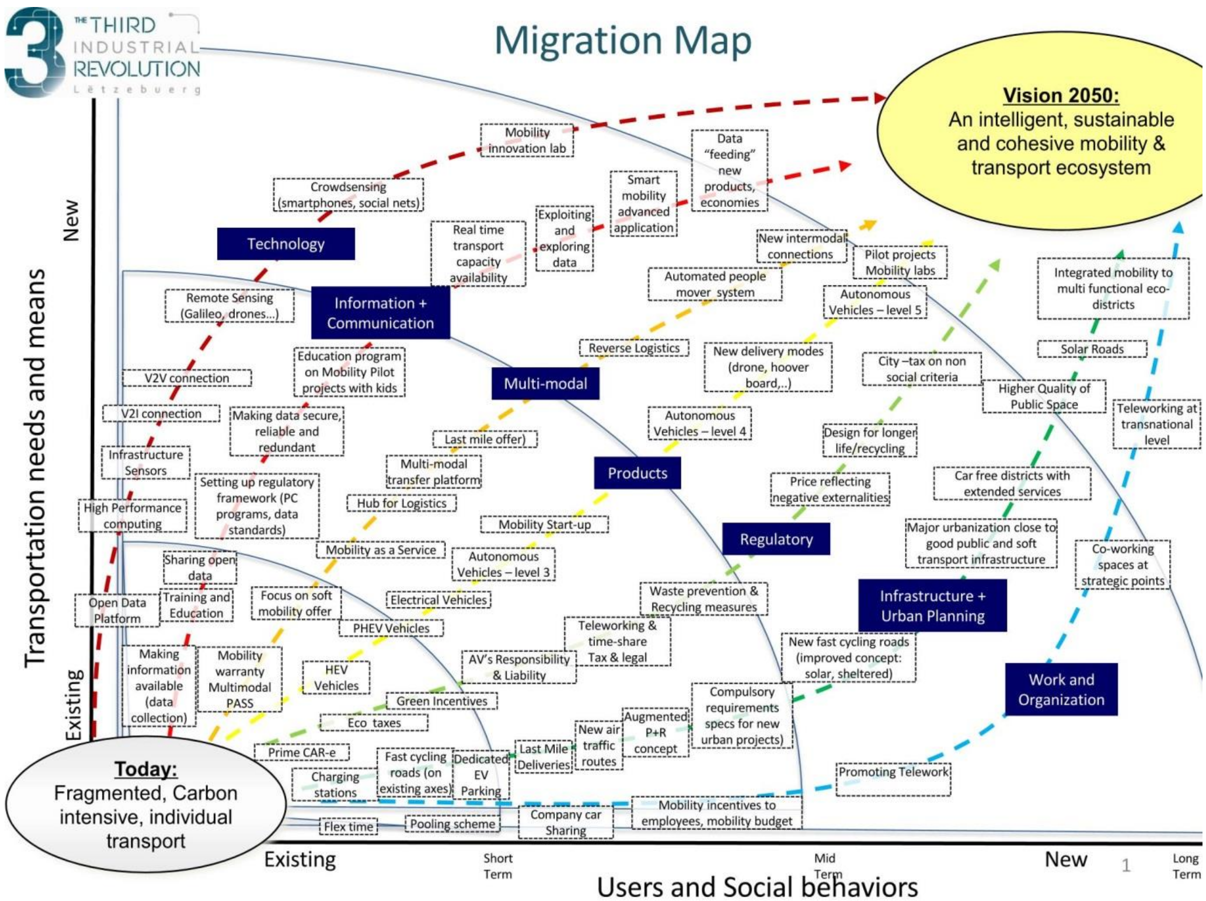
A corridor for testing and demonstrating new mobility solutions could be built in Luxembourg. This corridor would provide an experimental field for testing various mobility modes and technologies. Solar road sections, energy-harvesting paths, and solar roof systems supplying public lighting or e-bike charging stations are just a few of the systems that will require field testing. Since the emphasis is put on fast cycling roads (see section 4.1.1), this new generation testing corridor could be potentially also used as a fast cycling lane.

Mobility demonstrating cooridor concepts around the world

ACTION PLAN

The evolution process from a "fragmented, carbon intensive individual transport" to the 2050 Third Industrial Revolution vision has been visualized through a graph (Migration Map) where "user and social behavior" (horizontal axis) and "transportation needs and means" (vertical axis) are correlated.

The "isochrone curves" visualizes the dimension of time and helps place the interventions listed in a timeframe helping to show what will be done first and what will be done later.



Migration map from the Luxembourg Working Group which served as input for developing recommendations on the mobility pillar.

The migration map shows the fundamental steps that need to be implemented in terms of Transport and Urban Planning actions (plans, norms, infrastructures, feasibility studies and pilot tests) in order to define a clear and coherent framework for a quick and effective transition.

GLOSSARY

EV: electric vehicle, general definition of a vehicle powered by an electric motor

BEV: battery electric vehicle: electric vehicle with power storage batteries on board

HEV: hybrid electric vehicle: vehicle with an electric motor and a non-electric motor (generally fossil-fuel powered) that can serve as generator of electric power (serial HEV) but also to provide traction directly (parallel HEV)

PHEV: plug-in Hybrid electric vehicle; hybrid vehicle with capacity to recharge its batteries through the distribution network, and eventually to release energy to the network

Hydrogen-Fuel cell (HFC): a device that uses the energy from the oxidation of hydrogen gas to produce electricity. The combustion exhaust gas is water vapor.

Automated vehicle: a vehicle fitted with automation devices that assist the driver in maneuvers such as speed control, braking, steering, obstacle avoidance. Fits SAE categories II and higher

Autonomous vehicle (AV): a vehicle that can travel without being guided by a human driver, but may retain a driver's seat and controls. Fits SAE categories IV and higher

Driverless vehicle: a vehicle without a human driver. Also driver’s seat and controls are missing. Fits SAE category V

Car sharing: a vehicle whose use is shared in time among many users, who typically pay a participation fee plus a usage fee. The access to the vehicle is exclusive and the users pay for the time they have access.

Ride sharing / car pooling: various users share a vehicle at the same time along the same route. Users typically register to the service for free and pay the owner for the use of a vehicle which is generally private.

Active (or soft) mobility: mobility that requires the use of one’s muscles and can provide significant health benefits. Typically it includes walking, cycling and e-cycling. May include other means such as skateboards, stand-on scooters and skates

BUILDINGS

OVERVIEW

Co-Chairs Pitt Mathieu and Vanessa Tarantini, assisted by Nico Steinmetz, and the Luxembourg Building Working Group;

Gerhard Stryi-Hipp (Fraunhofer ISE), Claude Lenglet (Co-European Director, TIR Consulting Group LLC), and Jeremy Rifkin, TIR Consulting Group LLC

Luxembourg will need to transform its stock of 140,000 residential buildings and 5,000 commercial and industrial buildings and its existing infrastructure into smart, digital buildings and networks across an Internet of Things platform to usher in a Third Industrial Revolution. The country projects a population growth, increasing from roughly 560,000 people in 2015 up to about 1 million inhabitants in 2050. In effect, Luxembourg is potentially the fastest growing population in the EU-28 through the year 2050. By comparison, the EU population is expected to grow by only 0.1% annually over the years 2013 to 2050, while Luxembourg would grow 1.8% per year over that same time horizon. The potential increase in population could provide an opportunity to build out and scale up a new generation of neighborhoods and buildings and accompanying infrastructure.

Buildings connected to the Internet of Things infrastructure will play an increasing role in data handling, green power production, energy storage, and act as transport and logistics hubs to manage, power, and move economic activity in a smart Luxembourg. The build out and scale up of a new generation of neighborhoods and buildings can advance aggregate efficiency, increasing productivity and reducing marginal costs and ecological footprint, making Luxembourg one of the most competitive and ecologically sustainable commercial spaces in the world.

First, buildings will have to undergo deep retrofitting operations, to seal their interiors, minimize energy loss, and optimize efficiency. Second, smart Internet of Things technology will need to be installed throughout the interior and exterior space surrounding buildings. Buildings will become nodes connected to every other building across the infrastructure to allow families, businesses, and communities to monitor Big Data flowing along the value chains and use analytics to create algorithms and apps that can increase their aggregate efficiency. Third, renewable energy harvesting technologies – solar, wind, geothermal, and biomass – will need to be installed in and around residential, commercial, and industrial sites to generate green electricity, heat and cold for immediate use within the buildings or sale back to the electricity, heating and cooling grid. Energy storage technologies, including batteries, hydrogen fuel cells, and thermal storage tanks, will need to be installed alongside the renewable energy harvesting technologies to store intermittent green energy for use or sale back to the energy grids to ensure a reliable supply of energy. Fourth, electric charging stations will need to be installed in or alongside buildings to power electric vehicles for use on the automated, GPS-guided and driverless passenger and freight vehicles of the Transport and Logistics Internet.

The return on investment in energy efficiency and energy savings takes place over relatively few years, after which the owner or renter enjoys a reliable stream of savings on its energy cost for decades. Studies show that retrofitted energy efficient buildings that serve as digital nodes enjoy a higher market value, higher rents, and higher occupancy rates. A typical study of residential buildings across France shows a 40% increase in market value for buildings receiving the top energy performance certificates.[97]

More importantly, transforming every building in Luxembourg into an Internet of Things data center, green micro power generating facility, energy storage site, and automated transportation hub greatly enhances their economic value by providing a range of high-tech services that dramatically increase aggregate efficiency and productivity and lower marginal cost in the managing, powering, and moving of economic activity. The increase in productivity and reduction in marginal costs, when amplified by thousands of buildings that become nodes linked to an Internet of Things infrastructure, not only appreciates the value of the building stock but also advances the economic growth of the Luxembourg economy.

Retrofitting every residential, commercial, and industrial building is a herculean task, but also an essential pre-requisite for transforming the economy into an Internet of Things Third Industrial Revolution. Insulating existing and new buildings, installing new, more efficient HVAC equipment, and introducing highly efficient LED lighting, all generate additional GDP while increasing the aggregate efficiency and productivity of the buildings’ operations. The introduction of an Internet of Things infrastructure in every building and between buildings to monitor and manage energy efficiency, while still nascent, is expected to grow exponentially in the next few years as Luxembourg transforms its building stock into smart, digital nodes interconnected in vast digital networks.

Germany’s considerable experience in retrofitting provides a metric for the job creating potential in Luxembourg as it embarks on a nationwide retrofitting project. The German Alliance for Work and the Environment is credited with the most ambitious retrofitting project

[97] Plan Bâtiment Durable. (2013). Immobilier et valeur verte : État actuel de la réflexion, 2013.

to date. 342,000 apartments were retrofitted, creating 25,000 new jobs and saving 116,000 existing jobs, or more than 141,000 new or saved jobs.[98]

Each one million dollars of spending on the manufacture and installation of envelope improvements generates 16.3 jobs when adding together direct employment, indirect employment, and induced employment. Each one million dollars of spending on HVAC improvements generates 13.3 direct, indirect, and induced jobs. Each one million dollars of spending on LED lighting creates 12.9 direct, indirect, and induced jobs. Each one million dollars of spending on Internet of Things technologies fosters 13.0 direct, indirect, and induced jobs.[99]

Fig. 1: Old and new buildings in Luxembourg City

Fig. 2: Historical facades in Luxembourg

Most of the existing 145,000 buildings in Luxembourg will need to be retrofitted in the coming decades. Luxembourg is already gearing up to engage in the largest retrofitting project in history. The initiative will create tens of thousands of new jobs while saving tens of thousands of existing jobs in the manufacturing, engineering, construction, and real estate sectors.

Financing the transition of Luxembourg's building stock to thousands of nodes that serve as data centers, micro power generating plants, storage sites, and automated transport hubs, will be financed and executed by a unique new business model called Energy Service Companies (ESCOs) and a novel financial instrument known as Energy Performance Contracts, also called Shared Savings Agreements. ESCOs finance the retrofits of buildings, the installation of

[98] See: http://warming.apps01.yorku.ca/wp-content/uploads/WP_2011-04_Calvert_Climate-Change-Construction-Labour-in-Europe.pdf

[99] Garrett-Peltier, Heidi. "Employment Estimates for Energy Efficiency Retrofits of Commercial Buildings." Political Economy Research Institute. 2011.

renewable energy harvesting technologies, energy storage, advanced meters, and electric charging stations with their own capital or bank loans, and the investment is paid back by the energy savings over time. The owner or occupant gets a free ride and after the payback period has ended, reaps the full value of the energy savings from there on. ESCOs generally include energy audits, project design, financing, purchase of equipment, and operation and maintenance.

Given the steep curve in the growth of the ESCOs market and Performance Contracting, it is likely that this mechanism, along with government incentives, will play a critical role in the conversion of thousands of buildings in Luxembourg into Third Industrial Revolution nodes to manage, power, and move economic activity across a smart green Internet of Things infrastructure. In the new Internet of Things era, everyone becomes their own efficiency expert and chief productivity officer, continually creating new apps to improve aggregate efficiency across their respective value chains.

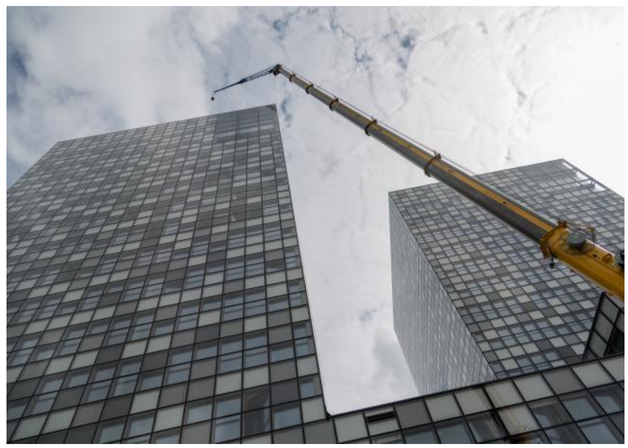


Fig. 3: Construction of a new office building in Luxembourg City
Source: http://paperjam.lu/news/rtl-bientot-dans-sa-city

STATE OF PLAY AND LUXEMBOURG VISION

The Luxembourg building stock is composed of 140,172 residential and semi-residential buildings regrouping 227,326 dwellings. Luxembourg's residential building stock consists predominantly of single-family houses representing 82.9 % of the building stock whereas apartment blocks represent 10.9 % and semi-residential buildings 6.1 % of the building stock.[100] The share of single-family homes in Luxembourg-Ville is about 21%, and in the other cities between 52% and 76%.[101] In 2010, the average floor space was 129.9 m^2 per dwelling.[102]

[100] See: http://www.statistiques.public.lu/catalogue-publications/regards/2015/PDF-06-2015.pdf and https://ec.europa.eu/energy/sites/ener/files/documents/NEEAP_LU_EN.pdf
[101] See: http://www.statistiques.public.lu/catalogue-publications/regards/2015/PDF-06-2015.pdf
[102] Luxembourg energy efficiency action plan 2014, page 71

Almost half of the building stock was built prior to the 1970s, while 17.8 % was built after the 2000s. There are significant differences between building types. 72.3 % of semi-residential buildings were built before 1971 and the majority of those (52.3 %) were built even before 1945, whereas this is only the case for 48.1 % of apartment blocks. For single-family houses, 50.5 % were built before 1970 and 12.9 % over the last 15 years. Apartment blocks are gaining in importance, so in terms of residential buildings built after 1995, the proportion of apartment blocks is greater than that of the single-family houses.[103]

Restoration or renovation of old buildings is more costly than demolition. Some 200 demolitions of residential and semi-residential buildings have been registered between 2011 and 2013 the majority of which concerned single-family houses. Buildings built before 1945 are the most commonly demolished (69.1 %) and buildings built after 1981 only represent 2.2 % of demolitions.[104]

Current national non-residential building stock[105]

The statistical basis for non-residential buildings is less complete than that which exists for residential buildings. In particular, there is an absence of statistical data for the period before 1970.

The table below gives an overview of the total number of buildings completed between 1970 and 2011, broken down by type of building.

Type of Building	Number	**Construction volume** (in m^3)	**Usable floor space** (in m^2)
Mixed-use building	1 618	7 544 741	2 179 294
Commercial buildings	936	14 877 014	3 268 224
Industrial and commercial	541	7 007 454	1 083 577
Agricultural buildings	471	1 383 830	306 822
Administrative buildings	262	6 418 599	1 415 209
Other buildings	508	3 977 195	700 700

[103] *Ibid.*
[104] *Ibid.*
[105] Source: Statec population census 2011, http://www.statistiques.public.lu/fr/population-emploi/rp2011/

Energy sources[106]

The table below provides an overview of the number of residential buildings by type, year of construction and fuel.

Building type and year of construction		Natural gas	Fuel oil	Wood	Elec-tricity	Other
Single-family houses	< 1971	49%	38%	3%	4%	7%
	1971 – 1995	40%	50%	2%	3%	5%
	> 1995	43%	42%	3%	3%	9%
Apartment blocks	< 1971	61%	30%	1%	3%	6%
	1971 – 1995	61%	34%	0%	3%	2%
	> 1995	74%	22%	0%	1%	3%

Energy performance requirements[107]

The energy efficiency policies are determined by several EU directives, mainly the directive on energy efficiency 2012/27/EU and on the energy performance of buildings 2010/31/EU.

The energy performance requirements from the Energy Performance of Buildings Directive (EPBD) for new and existing buildings in both residential and non-residential sectors are fully implemented. Among other measures, the national law implemented:

- a methodology to calculate the energy performance of buildings;
- minimum requirements for new buildings, extensions and renovated building elements of existing buildings;
- the Energy Performance Certificate (EPC)

Since 2012, Luxembourg has mainly implemented:

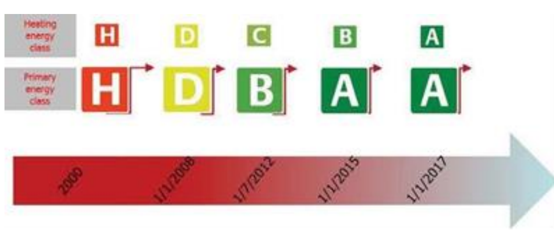
- a roadmap towards Nearly Zero-Energy buildings (NZEBs);
- an obligation to indicate the energy performance of buildings in advertisements;
- a timetable to reinforce energy performance requirements for residential buildings;

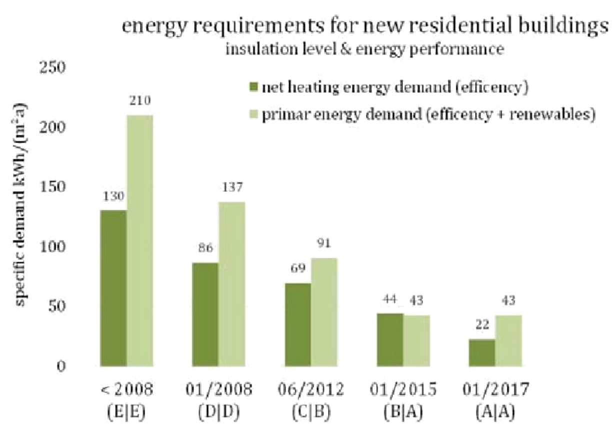
[106] Statec population census 2011, http://www.statistiques.public.lu/fr/population-emploi/rp2011/
[107] "Implementation of the EPBD in Luxembourg Status October 2014"

- a first step on the timetable to reinforce energy performance requirements for non-residential buildings;
- a cost-optimal study;
- an obligation for experts to upload their energy performance certificates of residential buildings into a database;
- a modification of the supporting financial scheme concerning residential buildings.

Luxembourg is gradually increasing the energy performance requirements of residential buildings (primary energy needs of the building) and the thermal insulation requirements (heating energy demand of the building). As of 1 January 2017, the A-A standard, which has also been defined, in principle, as the NZEB standard, will become mandatory. NZEBs will be highly energy-efficient buildings. For non-residential buildings, the energy performance requirements were reinforced as of 1 July 2015, increasing from the D-D (primary energy needs and heating energy demand) level required since 2011, to C-C level. The NZEB for non-residential buildings is expected to become mandatory from 1 January 2019 (the exact timeline and definition are still to be determined).

The first figure below shows the timeline of strengthening energy performance requirements for new residential buildings and the second one, the reduction of energy needs over time.





Building renovation

With regard to Article 4 of the Energy Efficiency Directive (EED), Luxembourg is still working on the final establishment of the national long-term strategy for mobilizing investment in the renovation of the national stock of residential and non-residential buildings, both public and private. In the Third National Energy Efficiency plan for Luxembourg, the development of the energy efficiency of buildings in the case of renovation has already been reported.

Element of the policy package	Policies implemented in 2011	Policy changes after 2011
Minimum Energy Performance Standards (MEPS)	• **Minimum energy performance standards (MEPS)** are in place and are to be tightened until 2016	• ☑ MEPS for residential buildings have been continuously tightened • Plans to further tighten **MEPS for non-residential buildings** from January 1 2015 • ✔ The Grand-Ducal Regulation of 26 May 2014 has stipulated that with effect from 1 January 2019 all **new buildings** (residential and non-residential) **must meet the nearly zero-energy standard.** However, a new regulation is in preparation, that provides the obligation for all residential buildings to be high energy efficient (passive house) by 2017, instead of nZEB by 2019.
Other Regulation	• No information found in the screened documents	• No information found in the screened documents
Grants, tax incentives	• **Investment aid for energy renovation**, the construction of a passive or low-energy house and the use of renewable energy • Provision of **subsidies for installation of solar panels, heat pumps for domestic hot water/ heating and PV for electricity generation** in households • **Tax credit for notarisation** when purchasing a property is partly linked to energy efficiency criteria	• ☑ Continued investment aid for energy renovation, the construction of a passive or low-energy house and the use of renewable energy • O Continued provision of subsidies for installation of solar panels, heat pumps for domestic hot water/ heating and PV for electricity generation in households • No information on developments regarding the tax credit for notarisation. • Plans to introduce an accelerated tax write-off of investments in energy renovations
Financing instruments	• **Subsidised interest rates for mortgages** linked to energy efficiency criteria	• No information on developments regarding subsidised interest rates for mortgages linked to energy efficiency criteria • Consideration of introducing interest-free loans to finance energy efficient retrofits for low-income households • Consideration of creating a public financial institution ('Climate Bank') to provide preferential loans for energy efficient building renovations
Energy performance certificates (EPCs)	• Introduction of **Energy Performance Certificates** (EPCs) for residential and non-residential buildings • **Qualification standards** for persons allowed to issue energy performance certificates for residential or non-residential buildings and online listing of these persons	• O Energy Performance Certificates (EPCs) for residential and non-residential buildings • O Qualification standards for persons allowed to issue energy performance certificates for residential or non-residential buildings and online listing of these persons

Fig. 4: Country Report Luxembourg on Energy Efficiency Policies in Europe 2014 for residential buidlings[108]

[108] Energy Efficiency Watch Project: Energy Efficiency in Europe, Country Report Luxembourg, 2014, download: http://www.energy-efficiency-watch.org/index.php?id=153

As part of the development of the final national long-term renovation strategy, surveys were conducted by TNS ILRES in 2015 on behalf of *myenergy* (www.myenergy.lu), the national energy agency, on households' attitude in relation to energy retrofititting in Luxembourg, in particular on planned housing measures like self-generation of electrical power (photovoltaic system, micro cogeneration unit, etc.) or households' equipment with "Smart Home" solutions for an intelligent control of heating and electrical appliances. (*cf. "TNS ILRES – La rénovation énergétique de l'habitat au Luxembourg - Volet Ménages*)

Luxembourg also intends to renovate 3% (4,000 m^2) of the national buildings owned and occupied by the central government each year. An overview on the energy policies in Luxembourg for residential buildings is given in Fig. 4.

Common Vision for the "Building" of the Future

The working group "Buildings'" approach focused on building development as well as on urban development. The group concluded that the slogan "**Smart, green and circular building in an optimal shared and attractive district"** reflects the main characteristics of the building of the future, whereas **"IntenCity"** summarizes their vision of an urban concept. We live in a time of digital revolution that is certainly changing the way we live and communicate and at the same time making communication between thousands of things around us possible in a manner never experienced before. However, compared to the terminology "Building as nodes," the group foresees a more people-oriented place for the building in a mixed and attractive urban setting and considers aspects such as proximity of things, circularity, sustainability and ecological aspects as integral part of the process.

With regard to building development as well as to urban development, the group structured the elements essential to realize the vision along the following categories: Green, Circular & Sustainable, Smart Technology, Energy, Information & Communication, and New urban concept.

The ICT-based technologies will be used to plan and construct intelligent buildings and will allow interaction between building operators and occupants to empower them with a new level of visibility and actionable information. Through optimized consumption and the ability to not only produce energy but also to store energy, smart buildings will play a role in stabilizing the grid. The connection to the grid will allow more flexible use of energy. At the same time, energy storage will become crucial for storing intermittent green energy for use or sale back to the energy grids. Deploying on-site energy generation systems and being energy self-sufficient go together with the aim of a smart building (such as small windmills/turbines, photovoltaic panels and solar heating collectors, and micro fuel cells). With regard to the energy sources, the group concluded that energy sources of the future will be renewable – mainly photovoltaic, due to the increasing role of electricity in the energy mix. The role of electricity will increase and heat will also be supplied by electricity even if geothermal energy will also play a role. Instead of each building being individually heated, whole districts (neighborhoods, cities, etc.) are served by a district heating network distributing renewable energy and waste heat.

Although the working group believes that "energy" certainly will guide the concept of a smart building, it is also the group's approach to refocus on the homeowner/occupant and stress the high quality of life that is largely dependent upon the construction materials used. The "IoT" is the data layer of a smart building, but circularity (design for modularity, flexibility, component and material recovery) and sustainability aspects must be added on top. Building smart means using the best available technology, yet at the same time it also means promoting good health and a sound environment for the people who will use it. It seems important for the group to add the concept of "noble functions of a building" which can greatly contribute to enhance and support the implementation of the principles of circular economy. The group stresses a focus only on using circular materials and entire re-useable structural elements, so that the notion of waste will completely disappear. The group brought up ideas such as including a rational bioclimatic architecture and urban farming in the concept of a building. Urban farming fits perfectly within the cities of the future and intelligent buildings should incorporate the functions of urban farms and greenhouses to bring back agricultural aspects to the cities. However, the competition for the use of roof space between solar energy generation and urban farming must be taken into account.

In order to achieve the construction of the building of the future, planning will become a very important aspect. Reaching the "vision requires adding intelligence from the beginning of the design phase through the end of the building's useful life."[109] Tools such as BIM (Building Information Management) allow considering the approach through the complete value chain from design to construction to dis-assembly and reuse of materials and elements. As of the planning phase, smart rational buildings should be established and the actual building form should change. Buildings should not only remain residential buildings but should become more flexible and multifunctional. Additionally, considering the fact that Luxembourg has many old architectural buildings, the destruction of those buildings should be avoided in order to preserve the cultural heritage. The aim is to become inventive with regard to retrofitting and transforming existing buildings into green power plants. With regard to the existing building stock, the group supports retrofitting rather than demolition when it is more sustainable. Old and new, historic and futuristic, should be combined by taking into account the "human" aspect

[109]See: http://www.buildingefficiencyinitiative.org/articles/what-smart-building?

and keeping the "beauty" of a building (reference Vincent Callebaut). The group supports that retrofitting of existing buildings shall be promoted and developed to a maximum, without introducing an obligation to retrofit but granting incentives in a short time frame.

Luxembourg's expected economic and population growth as well as the country's size, will lead to dense urban and rural environments in the future, requiring careful analysis at the buildings and urban development levels. The group retained the terminology *"IntenCity"* for the urban concept of the future. The group does not only foresee the urbanization of the main cities of the country, but considers urban development over the whole country (eco-neighborhoods, cities, grouping of different municipalities, etc.). These issues are also part of the new sectorial plans for housing, economic activities and landscape.

"Inten" because a city should become *intense* through attractive urban design and planning strategies leading to lively public spaces that articulate the many different usages and users. The concept of *IntenCity* will embrace art and culture, individual initiative/shared responsibility, as well as changes across time, age, old and new. Through a more collective spirit the quality of life of each individual could be enhanced. *"IntenCity"* is an urban development vision that integrates multiple information and communication technology (ICT) solutions in a secure way. ICT is used to improve performance, quality, and interactivity of urban services, to minimize costs and consumption of resources and to enhance contact between goverment and its citizenry.

Smart and green building will be completely integrated in the *"IntenCity"* of tomorrow. Instead of considering only a building's "greenness" and "smartness," buildings will need to be analyzed within a much broader context by taking into account social, environmental and economic factors including the consideration of the timeline: from construction to disassembly and new assembly with the re-use of disassembled parts. Nature offers us many solutions to explore, and the city of the future shall be seen as a man-made human ecosystem. It is important to focus on efficient and livable cities as well as economically, socially and environmentally sustainable cities.

Preparing liveable and sustainable cities will have to take into account the potential catastrophic impacts that climate change will wreak on habitats and infrastructures. We have yet to engage a deep conversation on the question of building for "resiliency" on a planet whose weather patterns are changing exponentially and qualitatively in a matter of decades beyond anything experienced in the past 65 million years. In short, we need to begin thinking about a concept of "liquid infrastructure" that can accommodate environmental upheaval and mass migration on a local and global scale. Like every other country, Luxembourg will have to prepare a new generation of architects, engineers, urban planners, and ecologists in the erection and deployment of "mobile infrastructure and habitats" on a large-scale, similar to the way refugee camps and front line military outposts are set up. In the future, resiliency has to also include infrastructure and habitats that can be distributed, decentralized, and modular, to facilitate dismantlement, shipment, and reassembly in new locations.

We also need to develop a more sophisticated approach to integrating infrastructure, human habitats, and living patterns with the complex dynamics that animate the evolution of natural ecosystems, learning from the approaches to short-term and long-term resiliency that evolve in natural ecosystems as guides to future human development patterns. This will require focusing greater attention on stigmergic self-organization, emergence, and complexity theory in modeling the liquid infrastructures and habitats of the future.

An important step toward transforming Luxembourg's building stock into nodes connected to the Internet of Things platform is the development of education and training. Education and training should be implemented in all the education layers, and the basic education programs of the future generations should consider specific courses on energy strategy and "*IntenCities"* objectives.

The building sector is a core element of the TIR roadmap. Buildings are responsible for 40% of energy consumption and 36% of CO^2 emissions in the EU.[110] Buildings are durable and play an important role in the economy as investment and property. They allow privacy and define public spaces between them and they are key elements forming a city. In the past, buildings often provided only a room to be protected against the weather, with low thermal and other comfort. In the future, buildings will provide optimal comfort through intelligent and efficient design and infrastructure as well as ICT systems, which can read the needs of the occupants and provide a comfortable environment. The buildings will be equipped with a high number of sensors and intelligent control systems gathering data, which enable the HVAC system to provide: fresh air at the right temperature depending on the oxygen demand; perfect light combining daylight and the light spectrum adapted to the needs of the occupants; as well as highly efficient use of heat, cold, and electricity, energy generation on the façades and the roof via solar systems and an optimal connection to ICT services for entertainment, information, communication, and education. Additional services include personal health assistance and supplementary childcare support.

With the the Third Industrial Revolution, the Grand Duchy of Luxembourg is aiming to actively prepare and stimulate the transformation process in the building sector. In 2015, the total energy demand for heating was 5,723 GWh in the residential sector.[111] Taking into account the

[110] See: http://ec.europa.eu/energy/en/topics/energy-efficiency/buildings
[111] STATEC projection 2015. Delivered to TIR Consulting Group in January 2016.

average floor space and the number of dwellings, the heat demand was 194 kWh per m^2 floor space per year on the average. In comparison, the heat demand in 2014 in Germany was 149 kWh/m^2, but with a significantly lower share of single-family buildings than in Luxembourg.

A key task is to reduce the energy demand for heating in buildings significantly. The technologies and products for energetic refurbishment are available and numerous projects prove that even a passive-house standard can be achieved by refurbishment. However, the country is faced with a large share of historical buildings, where the protection of the façades limits the possibilities of energetic refurbishment (at least at reasonable costs). In these cases, GHG reduction must be achieved by providing the heat with renewable energy sources (RES). Between 2001 and 2010 only 18,330 refurbishments were carried out in residential buildings, and only a part of them was energetic refurbished.[112] Therefore, the energetic refurbishment rate is below 1% of the building stock per annum and must be more than tripled to refurbish all existing buildings until 2050.

Another challenge for the country is the expected growth of the population up to about 1 million inhabitants by 2050, which means an increase of 80%. Assuming that the trend of growing living area per person and declining occupants per dwelling continues, the number of dwellings and the living space will almost double. However, this development is also an opportunity for the country, since for new buildings, from 2017 on, the Nearly Zero Energy Building (NZEB) standard is mandatory, with an energy requirement of 43 kWh/m^2/a primary energy demand (incl. renewable energy). With almost half of the buildings being built according the NZEB standard, the average specific heating demand will decline significantly. Assuming that 40% of the single-family homes and 15% of the apartment buildings are historical dwellings with very limited refurbishment possibilities, it can be calculated that a reduction of the average heat consumption by 65% per m^2 living area and of 33% for total heat demand can be expected due to the high share of new buildings (see Figure 5).

The building working group provided a clear vision and is aiming for “Smart and green buildings in an optimally shared and attractive district.” As further described, the buildings will be green and sustainable, using smart technologies, and will be mainly supported by renewable energy sources as part of a new urban concept. On the district level, an “IntenCity” provides an attractive urban design with lively public spaces, art, and culture, and supports individual initiatives and shared responsibilities, while integrating multiple Information and communication technology (ICT) solutions in a secure way.

[112] Luxembourg energy efficiency action plan 2014, page 70

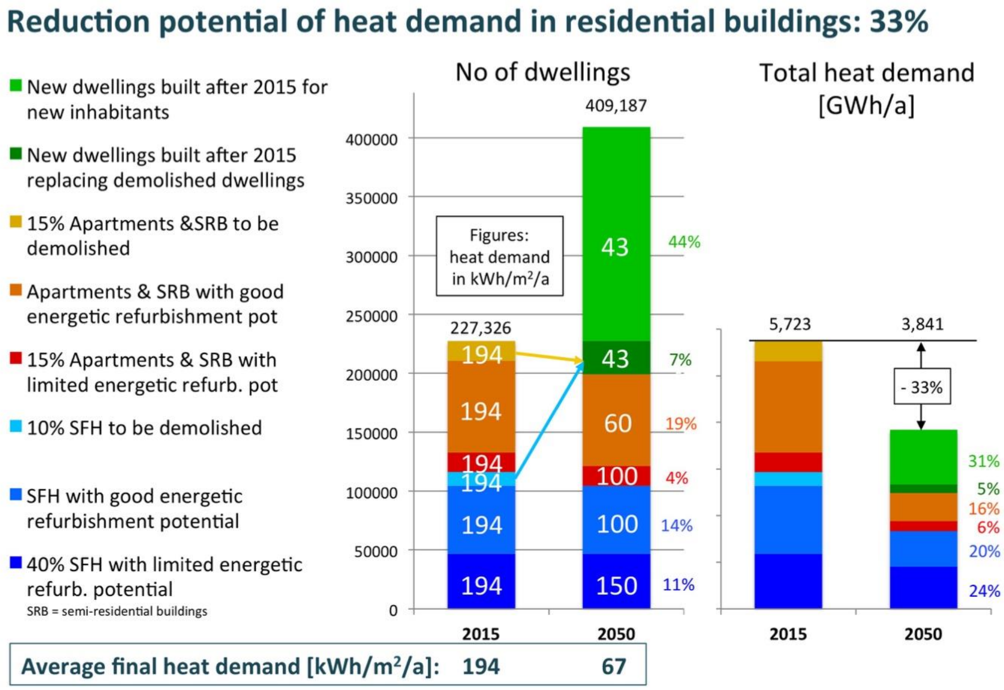


Fig. 5: The change in the number of dwellings and resulting total heat demand from 2015 to 2050 distributed by type of dwelling and related final average specific heat demand

Within a district or eco-neighborhood, Third Industrial Revolution buildings will be energy self-sufficient through efficient energy use and the generation of energy on-site, mainly by photovoltaic. Due to electrical storage capacities, buildings will stabilize the electrical grid. The Working Group expects that the use of electricity in buildings will also increase in the heating sector and that geothermal will be used in every district.

Buildings will be intelligent by using building information and modelling (BIM) technologies on the entire chain from design, construction and operation up to disassembly and re-use of elements and materials. This contributes to the aim of total circularity, where no waste is generated in the construction sector, since only circular and re-usable materials are used.

Luxembourg is also emphasizing the need to ensure a high quality of life in the future by ensuring that buildings assist in providing a healthy and sound environment for the occupants. The Working Group emphasizes that quality of life depends, at least in part, on the construction material. A good building design also requires abundant daylight and adequate sun protection.

Comparison of building renovation paths in Europe: In the shallow renovation path the minor renovations continue to represent most activity over the next two decades (top), in intermediate renovation path minor renovations continue to be most common for the next decade, but fall away and deep renovations grow to 65% of activity by 2050 (middle), in the deep renovation path, deep renovations become the dominant activity by the end of this decade and remain so until 2050. Source: BPIE

Tab. 1: Comparison of results of three building renovation paths in Europe, Source: BPIE

Renovation path:	Shallow	Intermediate	Deep
2050 saving as % of today	32% - 34%	48%	68%
Investment costs (present value)	€bn 343 -451	€bn 551	€bn 937
Savings (present value)	€bn 530 – 611	€bn 851	€bn 1,318
Netsaving (cost) to consumers	€bn 160 – 187	€bn 300	€bn 381
Netsaving (cost) to society - without externality	€bn 4,461 – 4,884	€bn 7,015	€bn 9,767
Internal Rate of Return	11.5% - 12.4%	12.5%	11.8%
Annual net jobs generated	0.5 Mio	0.7 Mio	1.1 Mio

Source: Buildings Performance Institute Europe (BPIE): Europe's buildings under the microscope, Oct 2011

The working group also highlighted the role of buildings in the TIR as nodes and service providers in an Internet of Things infrastructure. Buildings will be zero energy or plus energy buildings within a district/eco-neighborhood through: optimizing the balance of efficiency (insulation of the building envelope); the passive use of solar energy via south-facing windows; the generation of electricity and heat on-site on the façades and roofs; solar energy, biomass driven combined heat and power units (with gas motors or fuel cells); and using heat pumps to generate heat from renewable electricity.

The overall aim of buildings is to protect the occupants from the weather, noise, and bad air, and to provide a healthy environment which is well tempered, provides daylight and fresh air, and enough space for people and goods. Buildings will also provide a perfect connection to the outside world by ICT for entertainment, information, communication and education. And buildings provide fresh water and facilities for disposal of waste, sewage water, etc. In addition, urban farming is of growing interest and could be a service provided in, on, or around buildings.

Buildings as physical structure and infrastructure provider

- Static structure, facades and roofs: thermal and noise insulation, weather protection, daylight use, passive solar energy use, energy generation, façade to public space, place for food growing
- Provider of technical infrastructure: energy generation / thermal and electric storage / air conditioning
- Provider of ICT infrastructure: Cable and Wireless LAN, data storage
- Building ICT system, smart home

Buildings as comfortable place to live

- Sufficient space for people and goods
- Protection against uncomfortable temperatures, noise, polluted air, heavy daylight
- Providing security and private space, separating private from public space
- Provide light, water, communication and information
- Supports disposal of sewage water, waste, used materials and goods

Buildings as property item

- Property
- Rented apartments: investor – tenant dilemma
- Living space as human right = social question
- Affordability of owning and renting
- Profitability / investment attractiveness for investors
- Heritage for the new generation

(Urban) Environment of the building

District ecosystems providing key services:

- Mobility (individual, public,…)
- Social life, attractive public spaces for leisure, culture and recreation,…
- Food, goods,…
- Nature, sun, water, clean air,…
- Jobs
- Health and care (children, elderly,…)
- Education (kindergarten, schools, university, professional training,…)

Buildings as material consumer and waste producer – Ciruclar economy concept	**TIR Transformation process**
• Minimize the environmental impact of the material used for construction • Optimize design, planning, construction, operation, disassembly, Re-use of sustainable materials	• Participation of stakeholders • Financing of investments, refurbishment • Subsidies, regulation, legislation • Public responsibilities? • How to introduce innovations? • Governance of transformation? • Education

Fig. 6: Fields of action in the building sector for implementing the TIR roadmap

Urban planning will also need to focus on the public space between buildings with accessible streets, bicycle and foot lanes and places to meet and play. These features significantly impact the social life in the district. Additional needs include access to shops, education, culture, and jobs, all of which are very much influenced by urban planning. Building façades are the walls of the public space and characterize it. In cities with large buildings, façades are often used for advertisements and information and contribute to the lighting of the public space.

The construction industry is also an important business sector. Buildings are often the most significant forms of property people possess and the quality of buildings plays an important role in their personal wealth. In addition, the construction process should be viewed as a high-priority challenge, to be addressed by the TIR roadmap using BIM tools to expedite high-quality planning, construction, operation, refurbishment and dis-aggregation and reuse.

All these aspects of the building sector, which are shown in Fig 6, should be taken into account by identifying necessary actions as part of the TIR transformation process in the building sector.

The TIR proposals for the building sector focus on refurbishment of residential buildings, an action plan for non-residential buildings, integral and sustainable concepts for the construction sector, lighthouse districts, and resiliency.

Resilience for the Built Environment

Climate change is dramatically transforming the water cycles of the Earth, giving rise to unprecedented winter snows, extreme spring floods, dramatic summer droughts and wildfires, unprecedented heatwaves, and Category 3, 4, and 5 huricanes. The result is catastrophic impacts on human infrastructures and the built environment. Existing buildings in communities around the world were not designed to withstand these climate related events.

Escalating environmental disruptions are now accompanied by the increased threat of cybercrime and cyberterrorism aimed at shutting down critical infrastructure – communication, electricity, and transportation – that could bring society to a halt, with dire implications for communities around the world.

Cities, regions, and countries are just now turning their attention to the issue of resilience and exploring radical new approaches to securing the built environment. Conventional policies regulating the built environment are proving to be woefully inadequate in addressing the disruptions. City planning is being rethought virtually everywhere. Securing buildings against catastrophic disruptions will increasingly become a key priority in ensuing decades. New codes, regulations, and standards will have to be established for new buildings in every region, tailored to local climate change risk conditions. Existing buildings will have to be audited and assessed in terms of their resilience to the new realities caused by climate change and the increasing threat of cybercrime and cyberterrorism. The retrofitting of existing builidng stock will become an essential centerpiece in an era increasingly characterized by modes of resilience.

PROPOSALS

The following proposals are prioritized to implement the TIR roadmap in the building sector.

1 Stimulate innovative and deep refurbishment of residential buildings

1.1 Technical: Promote the use of standardized construction elements and methods

1.2 Regulatory: Establish legislation to stimulate refurbishment of buildings

1.3 Public policies: Involve municipalities and stimulate local refurbishment action plans

1.4 Financial: Encourage refurbishment of buildings by financial support programs

1.5 Establish and implement an action plan for refurbishment of residential buildings

2 Turn non-residential buildings into TIR ready working places and data hubs

2.1 Technical: Promote the use of standardized construction elements and methods

2.2 Regulatory: Legislate urban context-adapted density and high-rise construction

2.3 RDI: Develop intelligent façades for non-residential buildings

2.4 Build up the LUX TIR Construction Platform involving all stakeholders

2.5 Develop and implement a TIR action plan for non-residential buildings

3 Introduce integral and sustainable concepts in the construction sector

3.1 Technical: Develop and implement a national BIM strategy

3.2 Regulation: Develop a TIR building certificate

3.3 RDI: Introduce circularity with the development of a “material bank for buildings”

4 Build up “Intencity” lighthouse projects

4.1 Technical: Demonstrate smart, green, and circular zero-energy districts

4.2 RDI: Strengthen the research sector for transitioning buildings and districts

4.3 RDI: Develop the University of Luxembourg as a TIR living lab

5 Create a Resilience Commissioner in charge of economic, societal and environmental resilience

1 Stimulate innovative and deep refurbishment of residential buildings

Under the recent building codes, newly constructed buildings in Luxembourg will be nearly-zero energy buildings from 2017 on and be in accord with the TIR requirements in regard to energy efficiency. However, additional actions are needed for existing buildings. Since the majority of existing buildings are residential, they should be the first to be retrofitted. The scale of refurbishment should increase significantly each year and should involve deep renovation to a high efficiency standard, since cosmetic refurbishments are not sufficient.

1.1 Technical: Promote the use of standardized construction elements and methods

The increased use of standardized construction elements and methods will stimulate the refurbishment of residential buildings because they reduce costs, refurbishment time, and disturbance of occupants of the buildings, while improving the quality of work, enabling a fast increase of the refurbishment rate.

Standardization, at the same time, supports the introduction of circularity by making it easier to reuse and recycle construction elements. But standardized can also mean the integration of different functions in one element, e.g. HVAC components like air ventilation ducts in the insulation layer of the building.

This technical concept should be promoted by setting up a working group of all stakeholders involved – architects, planners, construction companies, housing companies, governmental representatives, etc. – to collaborate in the development of an action plan for standardized elements, accompanied by commensurate regulations, incentives, financing, business models, and R&D. The Luxembourg government and the energy agency should promote this concept in their public relations work with owners of residential buildings.

1.2 Regulatory: Establish legislation to stimulate refurbishment of buildings

The heterogeneity of the market makes it necessary to set minimum legislative requirements on energy efficiency for existing buildings, taking into account the limited capacity to act by the government, since it is regarded as an invasion of the owner's property rights. However, there are opportunities for the government to act (e.g. the German state of Baden-Württemberg made it mandatory to use a minimum share of renewable energy sources for heating, if the heating boiler is replaced). A combined approach of requiring building owners to reduce their GHG emissions caused by their heating system by regulation while simultaneously motivating them to invest in a deep refurbishment with incentives seems the most promising approach to achieve the government goals.

1.3 Public policies: Involve municipalities and stimulate local refurbishment action plans

Municipalities are key actors in stimulating and supporting the refurbishment of buildings in their jurisdictions. Therefore, the government should join forces with the municipalities and incentivize them to develop and implement refurbishment action plans for residential buildings as part of the TIR roadmap deployment. Concrete actions could include:

- Build up a network of political leaders at the municipal level who are willing to implement the TIR roadmap, and motivate them to establish local action groups (e.g. architects, social housing companies, property developers, and construction companies).
- Identify, together with municipalities, potentially scaleable refurbishment projects that could become lighthouse examples for buy-in by other residential neighborhoods and commercial districts.

1.4 Financial: Stimulate refurbishment of buildings via financial support programs

Financial incentives are necessary to stimulate ambitious energetic refurbishment of buildings. For example, the German government provides loans for refurbishment via the state owned bank KfW. Subsidies are provided in the form of reduced interest rates and by waivers of a part of the loan rates.

Special support is needed for low-income building owners and the social housing sector. A fund should be set up to provide support for these target groups which could be financed by taxes on empty houses/apartments, on low efficiency secondary houses, on capital gains from rental properties already paid off, or on rental price changes (when they increase due to the pressure on the market and not due to renovation or upgrades). The state should provide additional funding from the national budget if the defined sources are not sufficient.

1.5 Development and implementation of an action plan for refurbishment of residential buildings

To overcome the barriers in refurbishment of residential buildings and to unlock the related potentials by combining it with other elements of the TIR roadmap like the generation of renewable energy and the usage of the buildings as energy storage centers and as nodes of the IoT infrastructure, a concerted action plan should be developed to transform the existing building stock. All relevant stakeholders should be involved, including the construction sector, real estate industry, housing companies, planners, government agencies, etc.

The action plan should combine the already existing initiatives and support schemes with additional actions based on a gap analysis. Priority interventions include:

1. Identify and quantify the needs, the targets (refurbishment rates, average energy consumption of the building stock per m^2) and the types of buildings and areas for renovation. Develop ESCO business models, financing schemes, and a "full service offer" for building owners from project design until final commissioning.
2. Start with a few predominant house typologies and develop initial projects. The start-up projects will serve as a learning curve for a large-scale and long-term deployment.
3. Develop a second phase with a massive scale-up of houses and/or other types of buildings.

2 Turn non-residential buildings into TIR ready working places and data hubs

Non-residential buildings are an important part of Luxembourg's construction sector. They correspond today to almost 9 Mio m^2 of floor space built since 1970[113] whereas the residential sector is close to 18 Mio m^2. These are mainly offices and public buildings which will provide a significant part of the infrastructure of the TIR economy, since they will become energy and data nodes of the IoT and provide the services for the new businesses and the TIR workforce.

The working environment will change radically in the post fossil-fuel age. Sharing work spaces, working together in teams in virtual settings, having access to Big Data on the Internet of Things platform, and using distributed 3D printing, are only a few of the game changing trends that will dramatically affect the way we work and conduct business in the future. Offices and public

[113] See : https://ec.europa.eu/energy/sites/ener/files/documents/NEEAP_LU_EN.pdf

buildings will provide much of the space and infrastructure for this development. Therefore, they have to be energy efficient and serve as energy producers and data hubs for the IoT and, at the same time, provide high quality work environments.

2.1 Technical: Promote the use of standardized construction elements and methods

While the standardized construction elements and methods for residential buildings (see 1.1) are equally applicable to commercial buildings, the latter require additional consideration. High-rise buildings with intelligent façades and which require the flexible use of space also necessitate more sophisticated digital infrastructure to support business services. Since there are specialized stakeholders involved in the development, construction and operation of non-residential buildings, a separate working group with these stakeholders should be set up to fix targets, identify regulatory changes that need to be implemented, and finance R&D. Sustainable concepts (see 3.1 – 3.3) should become an integral part of the action plan.

2.2 Regulatory: Legislate urban context-adapted density and high-rise construction

With the population of Luxembourg expected to increase to up to about 1 million inhabitants by 2050, workplace growth will also increase commensurately. The construction of non-residential buildings needed to provide these workplaces is potentially in conflict with land-use for residential homes, agriculture, and even nature preserves. However, if the country decides to grow as expected and become a flagship TIR model, the design of cities and villages will need to follow a different path in order to reduce the use of space.

To assure a high quality living and working environment in Luxembourg, spatial planning should be reviewed with the emphasis on increasing density in appropriate urban settings, while simultaneously curtailing urban sprawl and freeing up land to restore Luxembourg's biosphere reserves. These aspects will also be part of the new sectorial plan for housing. Providing sufficient public living spaces and attractive work environments should be a high priority and be developed with deep public participation. Commercial districts embedded alongside residential neighborhoods make up the critical components of a public commons and a dynamic community life. This approach to urban planning is far-different from the conventional separation of work life and social life that results in dead office districts after work.

The new legislation on urban planning should include:

- An ambitious plan for energy efficiency of buildings.
- The benchmarking of renewable energy generation in and around commercial buildings.
- The review of spatial planning with the emphasis on increasing density in appropriate urban settings.

- A mobility concept, which frees up more public living and meeting spaces and is in line with the TIR mobility roadmap (electric vehicles, public transport, car-sharing, etc.).
- Requirements for Key Performance Indicators for eco-design and the use of eco-materials in a Circular Economy.
- Measures to provide high resilience against natural disasters.

2.3 RDI: Development of intelligent façades for non-residential buildings

Intelligent façades control the light exposure, provide decentralized ventilation, protect against UV irradiation, contribute to electricity and heat generation by solar energy and support the cooling system of the building. In addition, they can play an active role in (digital) communication with the environment (e.g. by being a display).

Since it is expected that a growing number of large non-residential buildings will be constructed in Luxembourg, research will need to be prioritized to advance intelligent façades and smart building infrastructure.

2.4 Build up the LUX TIR Construction Platform involving all stakeholders

Several networks are already established and a myriad of activities are ongoing in the housing and construction sector in Luxembourg. In addition, the TIR working group on buildings brought together most of the stakeholders of the building and construction sector: architects, planners, engineering firms, real estate and construction industry, housing companies and associations, academia, and the energy agency of the government. These stakeholder groups now need to join together and oversee a Luxembourg TIR Construction Platform. The objective is to use the platform to implement the recommendations set forth in the TIR Strategy Study. A governing structure composed of the various stakeholders needs to be established and protocols need to be put in place to guide the operation of the construction platform.

The platform should be tasked with organizing education seminars, stimulating innovations in the construction sector, and collaborating with the other sectors of the TIR roadmap including energy, mobility, and digitalization. The TIR Construction Platform mandate should include urban planning and urban development, building information modeling (BIM), integrating circular economy principles, reducing construction costs, and introducing new business models to manage Big Data flows in buildings transformed into nodal networks of the Internet of Things infrastructure.

2.5 Development and implementation of a TIR action plan for non-residential buildings

Transforming non-residential buildings into Third Industrial Revolution nodes requires that the stakeholders of the TIR Construction Platform establish an action and implementation plan. The plan should address the following topics:

- Gather detailed data on the existing non-residential building stock to identify the low-hanging fruits for actions. The BIM concept should be implemented in the renovation of existing buildings and the construction of new buildings, with an emphasis on integrating the Internet of Things network throughout the non-residential building stock.
- Efforts should be made to quantify the market value of buildings that have been transformed into nodes that serve as Big Data center, micro power generators, and charging stations for e-transport.
- TIR state-of-the-art nodal building stock should be promoted across the EU and globally to attract businesses to a Smart Luxembourg.

3 Introduce integral and sustainable concepts to the construction sector

3.1 Technical: Development and implementation of a national BIM strategy

Digitalization is growing fast in all steps of the value chain of a building, from design, construction, operation, and refurbishment, to disaggregation, reuse of components and recycling of materials. However, up to now the different tools of building information modeling (BIM) used in the chain are often not connected. To unlock the efficiency potential of the digitalization of the construction sector, it is recommended that Luxembourg establish a BIM-toolchain, where all tools used in the chain access the same dataset of a building and add their results to this dataset, which then can be directly used by other actors. This means that there is only one dataset per building, including all data from the early beginning of planning until the final end of disaggregation and recycling of materials. This will increase efficiency, not only in construction and operation, but also in refurbishment, disaggregation and recycling of the construction and its elements.

To establish the BIM-toolchain requires extensive preparatory work. Among other things, the processes of the toolchain must be structured, interfaces defined, data protection rules developed, and data ownership questions and legal aspects resolved. Therefore, research and development, standardization and organizational work must be undertaken. The goal is to make the use of the BIM-toolchain mandatory for all non-residential buildings and to extend the process to all residential buildings.

3.2 Regulation: Development of a TIR building certificate

Luxembourg introduced the energy performance certificate (EPC) for residential buildings in 2008 and for non-residential buildings in 2011. The EPC must be presented when selling, leasing, renovating, extending, or constructing buildings. In implementing the EPBD Directive

2010/31/EU, new residential buildings must fulfil the nearly-zero-energy building standard from 2017 on. In 2014, the "Sustainability certification of residential buildings in Luxembourg"[114] guideline was published under the name LENOZ to evaluate not only energy efficiency, but also ecological, economic, and social aspects of buildings. In total, 145 criteria are evaluated in six categories. The sustainability assessment of buildings is being tested in the ongoing pilot phase.

These existing certificates assess the energy efficiency and the sustainability of buildings, which are important quality of life aspects of buildings in the TIR economy. A third aspect – the smartness of buildings – is growing in importance but not yet covered. Therefore, it is essential to develop a set of key performance indicators to assess the smartness of a building. This should include the level of connectivity to the IoT, the use of smart home technologies, the level of intelligence of the energy management system, and the provision of data hub services to other buildings. Based on all three performance indicators, a comprehensive certificate should be developed that includes energy efficiency, sustainability, circularity, and smartness. This would constitute a TIR Building Certificate.

3.3 RDI: Introduce circularity with the development of a "material bank for buildings"

Between 25% and 30% of the waste generated in the EU is caused by construction and demolition of buildings. This waste consists of materials like concrete, bricks, gypsum, wood, glass, metals, plastics, etc., many of which can be recycled. Since the European Union aims to be a society of recycling with a high level of resource efficiency, the Waste Framework Directive (2008/98/EC) regulates that Member States have to ensure that a minimum of 70% (by weight) of non-hazardous construction and demolition waste are prepared for reuse, recycling or material recovery.[115]

In December 2015, the European Commission adopted an ambitious **Circular Economy Package** to stimulate Europe's transition towards a circular economy and boost global competitiveness, foster sustainable economic growth and generate new jobs. The EU Action Plan for the Circular Economy promotes actions on production, consumption, waste management, and the marketing of secondary raw materials. The overall aim is to **close the loop of product lifecycles through greater recycling and reuse, and bring benefits to both the environment and the economy.**[116]

These EU initiatives underline the importance of the circular economy, which is an integral part of the TIR roadmap. The efficiency improvements in the TIR economy can only be achieved if

[114] Ministère du Logement: LENOZ – Luxemburger Nachhaltigkeits-Zertifizierung für Wohngebäude, October 2014, http://www.ml.public.lu/fr/lenoz/index.html
[115] See: http://ec.europa.eu/environment/waste/construction_demolition.htm
[116] See: http://ec.europa.eu/environment/circular-economy/index_en.htm

construction elements and materials are reduced, and reused and recycled after the end of life of the building. To reduce the volume of materials, enable the highest share of reuse of construction elements, and improve the quality of recycling of construction elements and materials, the knowledge of all materials used in the buildings is needed. Therefore, it is necessary to develop a "material databank for buildings," which gathers all information on materials (origin, volume, environmental data, etc.) used in a building from construction to disassembly. This will allow automized lifecycle assessments of buildings during the planning phase and the optimization of design based on the assessment of materials used. The information procured will also allow stakeholders to identify the "eco-friendliness" of the buildings. In the long-run, the material databank of a building will become a part of the BIM-toolchain dataset (see 3.1) and a certificate based on the eco-friendliness of the building and the ability of reuse and recycling (circularity) will become a part of the TIR building certificate (see 3.2).

4 Build up "Intencity" lighthouse projects

4.1 Technical: Demonstrate smart, green, and circular zero-energy districts

While the single technologies for TIR buildings, districts and cities are already available or under development, the implementation of all technologies in one district or city with all cross-linkages between the components of each of the three Internets – communication, energy, and mobility – and the IoT platform is not yet operational. However, only the implementation of the fully connected (sub) systems optimizes the aggregate efficiency and productivity gains that comprise a Third Industrial Revolution paradigm shift.

Therefore, consideration should be given to erecting two fully-operational TIR lighthouse districts in Luxembourg. One lighthouse project should be undertaken in a new Greenfield district since many new districts will be built in the coming decades to accommodate the population growth of Luxembourg. The other lighthouse project should be built out in an existing brownfield district where the challenges and opportunities are quite distinct and provide a different learning curve.

Moreover, the lighthouse projects should be embedded in mixed districts, which include residential, non-residential, and industrial areas, to build up living districts, make full use of the flexibility of the TIR infrastructure, and demonstrate synergy effects between the different types of buildings. The development and implementation of the TIR lighthouse districts will require the active involvement of all of the stakeholders: government (national and municipal), relevant businesses (construction, mobility, ICT, trade, financing, etc.), social groups, and the research sector. In addition, civil society organizations and residents of the districts should be involved in the conception, planning, and implementation of the lighthouse district to ensure active involvement and public support by the residents of the community.

4.2 RDI: Strengthen the research sector for transitioning buildings and districts

The construction of TIR districts requires a wide range of scientific and technological knowledge and expertise. This will require strengthening Luxembourg's research sector.

Research is needed on sustainable materials, construction elements, integration of functionalities, reusability of elements, refurbishment techniques, etc. Digitalization will enhance the design process in transforming buildings into nodes, while digitally mediated prototyping and virtual reality techniques will help establish the complex interconnections and synergies that optimize the building's Internet of Things infrastructure. Transforming buildings into intelligent, distributed, and cognitive systems will require the coming together of skills across academic disciplines, raising the bar for world-class academic and research centers. Luxembourg will need to invest in establishing biosphere valley research centers that can attract the best scientific talent from around the world.

4.3 RDI: Develop the University of Luxembourg as a TIR living lab

A university is not only the place for research and education of students, but also a campus and community, not unlike other neighborhoods or districts, with its own buildings, transportation modes, and public commons. Consideration should be given to transforming the University of Luxembourg into a "Living Lab", where professors and students from across the various academic disciplines can come together and transform the campus buildings and infrastructure into a nodal Internet of Things platform and Third Industrial Revolution test site for the research, development, and deployment of TIR technologies and concepts.

The scientific priorities of the University of Luxembourg include Computational Sciences, Finance, Security, Reliability, and Trust, and fit well with the implementation of the TIR concept. University researchers and students can actively participate in transforming their campuses into a smart digital TIR community.

5 Create a Resilience Commissioner in charge of economic, societal and environmental resilience

The Commissioner should monitor upcoming worldwide trends and coordinate the efforts to prepare Luxembourg's resiliency efforts. The building and infrastructure requirements in the emerging Third Industrial Revolution era are qualitatively different than in the past. Real-time climate change is dramatically impacting the water cycles of the Earth, resulting in extreme weather events – violent winter storms, dramatic spring floods, and prolonged summer droughts and wildfires. Buildings and infrastructure in the emerging era will need to be far more resilient to withstand unpredictable and life-threatening weather changes. This will require a rethinking of buildings and infrastructure. Luxembourg will have to prepare a new generation of architects, engineers, urban planners, and ecologists in the erection and deployment of "mobile infrastructure and habitats" that are highly flexible, dismantable, moveable, and resilient to withstand climate-induced environmental assaults.

The Resiliency Commissioner and agency should be independent and not be subordinated to other ministries, to allow a broad and unimpaired view on economic, social and environmental issues. Accumulating evidence and experience indicate that the laterally oriented and networked sharing and circular economy is more resilient and less prone to catastrophic disruption, than traditional vertically integrated, tightly linked linear supply chains. Tight linear supply chains are vulnerable to large disruptions causing catastrophic failures (e.g., Fukushima and Chernobyl reactors), whereas the laterally dispersed, richly networked features of the sharing and circular economy increase the likelihood of smaller disruptions that fail gracefully and can rebound more rapidly. Highly resilient buildings and infrastructure are at the core of the Third Industrial Revolution transformation.

5.1 Regulatory: Resiliency codes, regulations, and standards need to be established for all the structures in the built environment. Every building will need to be evaluated for vulnerability against climate change events. Evaluation criteria will need to factor in the type of construction, the age of the building, the technical equipment embedded in the building and the purpose of the building. Vulnerability categories should be defined and the buildings assessed against the different types of external disruptions. Such evaluation must be adapted to the use for which the building is intended, since the challenges facing single-family homes differ from public buildings like hospitals and schools or commercial buildings and shopping malls.

FOOD

OVERVIEW

Co-Chairs Christiane Wickler and Nancy Thomas and the Luxembourg Food Working Group;

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The phase in of the Internet of Things infrastructure for a Third Industrial Revolution portends vast gains in aggregate efficiency and productivity for Luxembourg farmers, food processors, wholesalers, and distributors. Farmers are already utilizing the emerging Internet of Things with sensors to monitor weather conditions, changes in soil moisture, the spread of pollen, and other factors that affect yields. Automated response mechanisms are also being installed to ensure proper growing conditions.

The agricultural Internet extends beyond the harvest to include the distribution of food to wholesalers and retailers. Sensors are being attached to vegetables and fruit cartons in transit to both track their whereabouts and sniff produce to warn of spoilage so shipments can be rerouted to vendors.

As the IoT infrastructure is phased in, farmers, processors, wholesalers, and distributors in Luxembourg will be able to mine the Big Data flowing across their value chains. They will be able to use increasingly sophisticated analytics to create algorithms and apps, allowing them to dramatically increase their aggregate efficiency and productivity, and reduce their marginal cost and ecological footprint in the managing, powering, and transporting of food, taking the food industry out of the chemical era and into an ecological era mediated by smart, new digital interconnectivity.

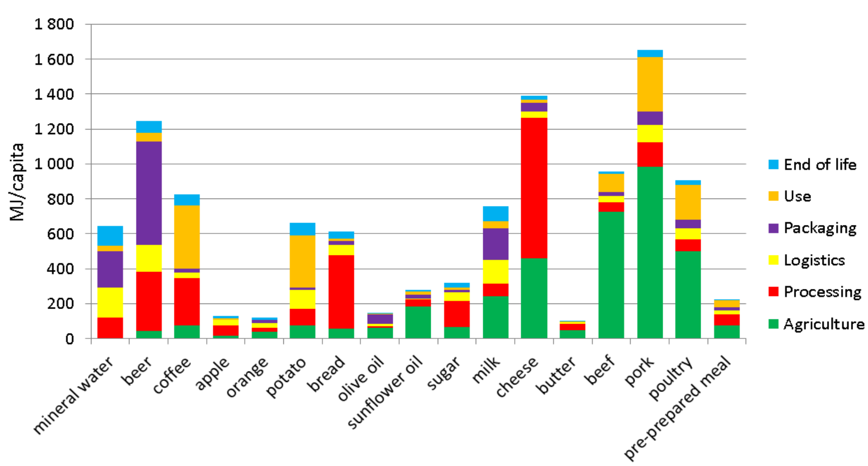
The Ag Internet introduces a new era of agriculture. It's called prescriptive planting and it is being heralded as a potential productivity leap in agricultural yields. Early trials boosted yields by approximately 5% over two years, marking an extraordinary jump in productivity.[117] Prescriptive planting combines remote sensors and cartographic techniques to map millions of acres of agricultural land and overlays the information with Big Data on climate across the regions. Analytics is used to mine the Big Data and provide precise times for planting as well as selecting the appropriate seed varieties best matched to the prevailing conditions.

[117] See: http://www.economist.com/news/business/21602757-managers-most-traditional-industries-distrust-promising-new-technology-digital

While a promising new set of technologies, the agricultural Internet of Things is not without controversy. Farmers worry that global life science companies might misuse the Big Data they are collecting to buy underperforming farms or that the Big Data might be sold to third parties or be used to trade on the commodity markets, undermining the price farmers receive for their harvests. In the United States, the American Farm Bureau, the nation's largest organization of farmers and ranchers, is introducing a code of conduct declaring that farmers own and control their data and that life science companies cannot use the information except for the purpose intended and cannot sell the data to third parties.

The food sector is a major consumer of energy in Luxembourg and across the European Union. The cultivation, harvesting, storing, processing, packaging, and shipping of food to wholesalers and retailers, uses massive amounts of energy. Petrochemical fertilizers and pesticides account for a significant portion of the energy bill. Operating farm machinery is also major energy expenditure. The cultivation of crops – especially the electricity bill used in irrigation – and animal rearing use the most energy in the food value chain, making up one third of the energy bill. The industrial processing makes up another 26% of total energy use. Packaging and logistics uses another 22% of the total energy expended. Final disposal of food waste makes up about 5% of total energy use; food waste is also growing, from 89 million tonnes in 2006 to 100 million tonnes in 2014 and projected to grow to 126 million tonnes by 2020.[118] Animal-based food production and refined food products require more energy than fruits and vegetables.

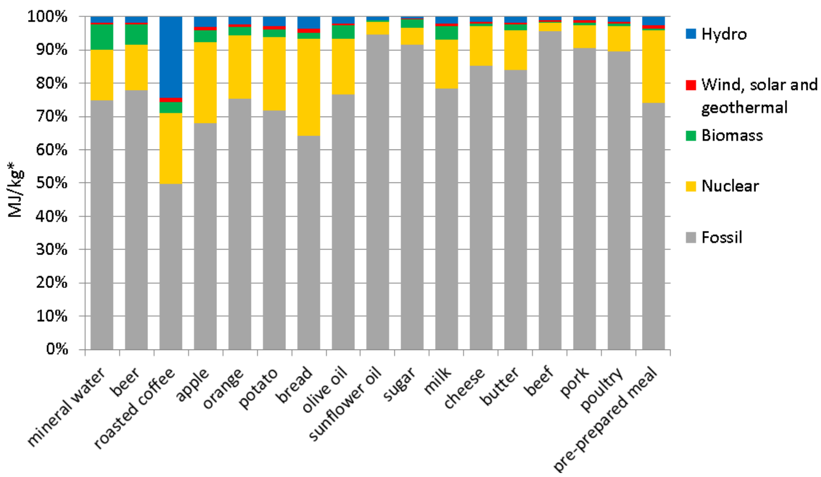
Amount of energy embedded in the JRC food basket in units of MJ per EU citizen, broken down for 17 products



Source: EC JRC (2015) Figure 1.1 Energy embedded in the JRC food consumption basket for the average EU citizen, broken down for products and production steps. Units: MegaJoules per capita (MJ/cap).

[118] See: http://iet.jrc.ec.europa.eu/remea/sites/remea/files/energysmartfood_pubsy_online.pdf

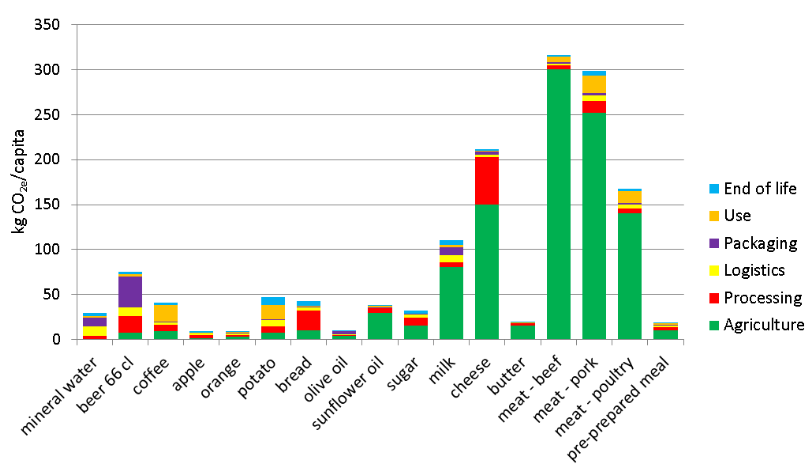
Sources of Energy embedded in the JRC food basket



Source: EC JRC (2015) Figure 1.5 Sources of energy embedded in each of the products making up the JRC food basket in relative terms. *Units in MJ/kg or MJ/l (for beer, milk and mineral water).

When all the energy costs associated with food production, distribution, and recycling are added up, EU agricultural food production is a whopping 26% of the EU's total energy consumption annually, making it a major contributor to greenhouse gas emissions. The food sector has lagged woefully behind other commercial sectors in increasing renewable energies, with only 7% of total energy used coming from renewable sources, in sharp contrast to 15% in the overall energy mix. Weaning Luxembourg's food sector off of petrochemical based farming is a formidable task.

Greenhouse Gas Emissions Per Product & Production Step



Source: EC JRC (2015) Figure 1.6 Annual GHG emissions related to the average EU citizen's consumption of the JRC food basket, detailed per product & per production step. Units in kg of CO2equivalent/capita.

The food sector is beginning to turn its attention to the challenge. Replacing petrochemical farming practices with organic ecological based farming practices is spreading across Europe and even in Luxembourg. Approximately 4,000 hectares of land in Luxembourg are currently being used for organic agriculture (this includes arable land, grassland, wineyards, fruit and vegtables).

The total retail sales of organic food are approximately €75 million annually (a large part of this turnover is still covered by imports from other EU-countries and beyond). Consumer demand is pushing the transformation. An increasing number of Luxembourgers are willing to pay premium prices for organic and sustainable foods.

Farmers are also joining together in the creation of electricity cooperatives and beginning to install solar, wind, and biogas energy technologies, creating a second business as micro power generators.

Changes in consumer dietary preferences are forcing a rethinking of farm practices. For example, intensive rearing of cattle and, to a lesser extent pigs, requires massive amounts of energy and is the most inefficient means of providing food in the agricultural system. It takes up to eight pounds of feed to create a pound of beef, making intensive cattle production and related animal husbandry practices even more inefficient than automobile transportation. A younger generation in Europe is beginning to wean itself off of a heavily meat-oriented diet and is consuming more fruits and vegetables.

Community Supported Agriculture (CSA) is a good example of the impact that new TIR business models are having on how food is grown and distributed. A century of petrochemical- based agriculture, in tandem with other technological innovations, spawned a vast increase in productivity and a corresponding reduction in the number of small farms. Now, a new generation of family farmers is turning the tables by connecting directly with households to sell their produce. Community Supported Agriculture began in Europe and Japan in the 1960s and spread to America in the mid-1980s. Shareholders – usually urban households – pledge a fixed amount of money before the growing season to cover the farmer's yearly expenses. In return, they receive a share of the farmer's crop throughout the growing season. The share usually consists of a box of fruits and vegetables delivered to their door (or to a designated drop-off site) as soon as they ripen, providing a stream of fresh, local produce throughout the growing season.

The farms, for the most part, engage in ecological agriculture practices and utilize natural and organic farming methods. Because community supported agriculture is a joint venture based on shared risks between farmers and consumers, the latter benefit from a robust harvest and suffer the consequences of a bad one. If inclement weather or other misfortunes befall the farmer, the shareholders absorb the loss with diminished weekly deliveries of certain foods. This kind of peer-to-peer sharing of risks and rewards binds all of the shareholders in a common enterprise. The Internet has been instrumental in connecting farmers and consumers in a distributed and collaborative approach to organizing the food supply chain. In just a few years, community supported agriculture has grown from a handful of pilots to nearly three thousand enterprises serving tens of thousands of families.

The CSA business model particularly appeals to a younger generation that is used to the idea of collaborating on digital social spaces. Its growing popularity is also a reflection of the increasing consumer awareness and concern about the need to reduce their ecological footprint. By eliminating petrochemical fertilizers and pesticides, CO_2 emissions from long-haul food transport across oceans and continents, and the advertising, marketing, and packaging costs associated with conventional Second Industrial Revolution food production and distribution chains, each shareholder comes to live a more sustainable lifestyle.

Finally, new cutting edge developments in the life sciences are opening up vast new opportunities for the agricultural sector. The fiber industry is introducing new biological based products as substitutes for petrochemicals in packaging, construction materials, enteric coatings for pharmaceutical products, and filaments for 3D fabrication and manufacturing, raising the prospects of additional income generation for farmers, growing specialized fiber-based materials that can replace petrochemicals in a range of commercial fields, along side conventional food crops. In the Third Industrial Revolution era, it will be critical to find the appropriate balance in using agricultural land for both food production and fiber production that can substitute for petrochemical products.

STATE OF PLAY AND LUXEMBOURG VISION

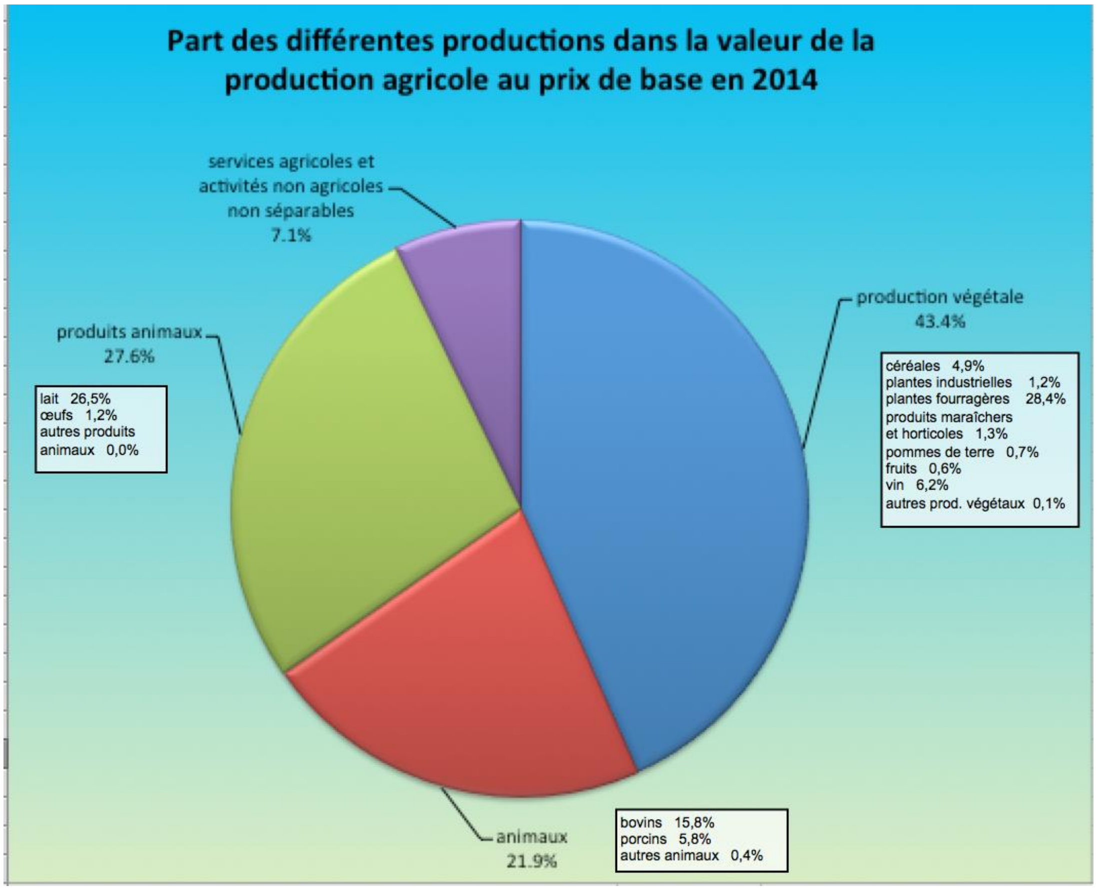
Luxembourg's food and agricultural contribution to GDP is approximately 0.3 percent. The gross value added from the agriculture sector has fluctuated over the past two decades from a high of €164 million in 2002 to a low of €80 million in 2009.[119]

Value Added Production

The chart below indicates the production value from Luxembourg's agriculture sector. Milk (26.5%) and forage plants (28.4%) represented more than half of the Luxembourg agriculture sector's total value.

[119] Source: Service d'Economie rurale, Luxembourg

LA PRODUCTION AGRICOLE



Source: Service d'Economie Rurale, Luxembourg

Value added is complicated by the terms and conditions set out by the EU's Common Agricultural Policy (CAP), which provides EU farmers annual Direct Payments under support schemes. According to the most recent EU Regulation No 1307/2013, Luxembourg's net ceiling is set at €33.6 million in 2015, slightly declining to €33.4 million by 2020.[120]

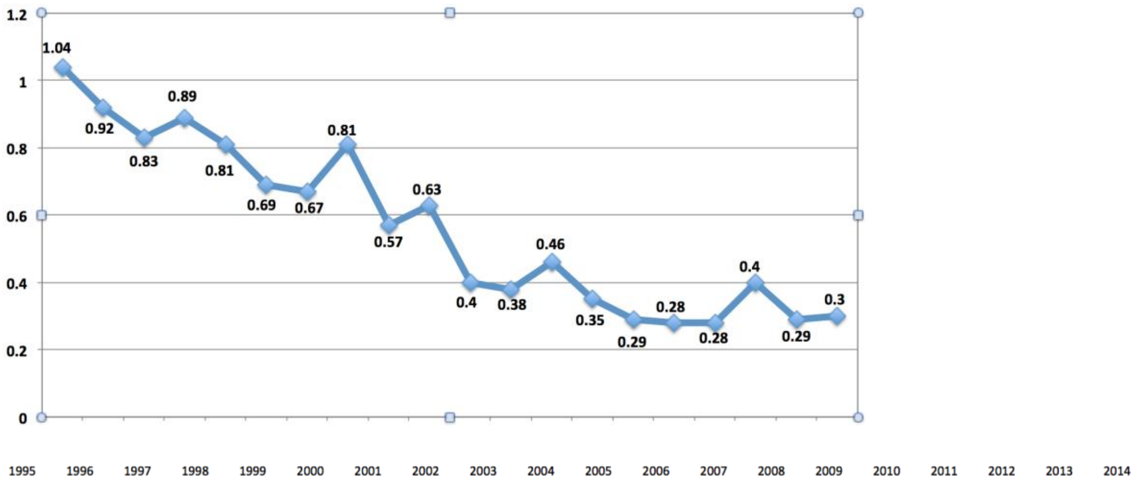
In addition to the first pillar, the second pillar of the CAP, implemented by the national Development Programme and by the new "agricultural law" (Loi du 27 juin 2016 concernant le soutien au développement durable des zones Rurales) provides almost €70 million per year of

[120] EU (2013) REGULATION (EU) No 1307/2013 of the European Parliament and of the Council, of 17 December 2013, establishing rules for direct payments to farmers under support schemes within the framework of thecommon agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009, Official Journal of the European Union, December 12, 2013, http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399363392444&uri=CELEX:32013R1307.

financing, mostly for agri-environment and climate measures, for investment aid, and for innovation partnerships.

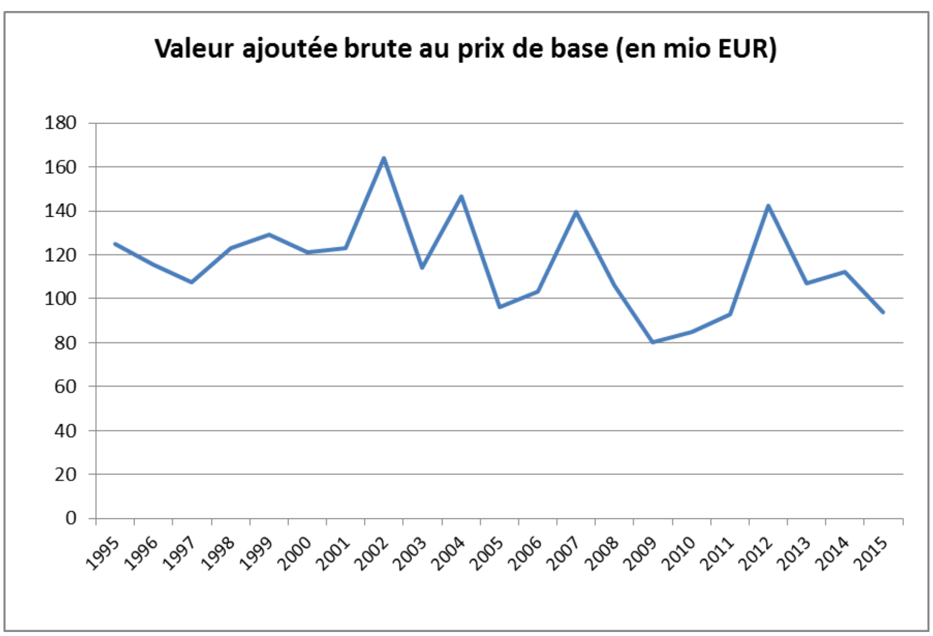
Luxembourg's agriculture sector has experienced significant fluctuations from year to year. These two-decade trends are shown in the following three charts.

Luxembourg Agriculture Sector as percent of Annual GDP (1995-2014) (%)



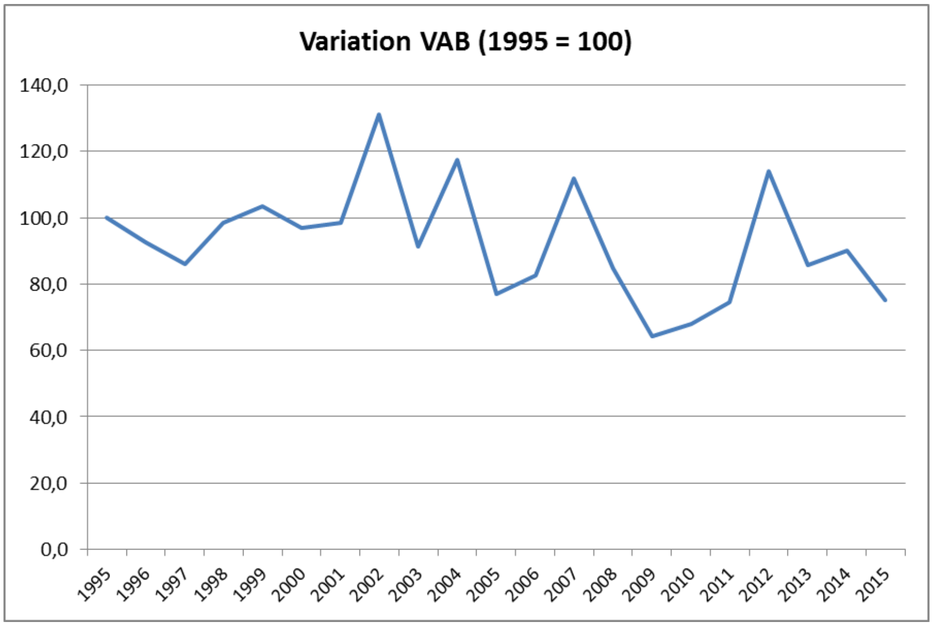
Source: Indexmundi, http://www.indexmundi.com/facts/luxembourg/agriculture

Luxembourg Agriculture, gross value added (1995-2014) (millions)



Source: Service d'Economie rurale, Luxembourg

Luxembourg Agriculture Sector, gross value added (annual % growth)



Source: Service d'Economie rurale, Luxembourg

Luxembourg's total agricultural labor force has declined by half since 1985, and now amounts to roughly 3,500 "annual work units" (AWUs, or full-time equivalents). Farm automation may account for a substantial percentage of the labor reduction, but no figures were available. This included 42,000 working days by day laborers (or 154 AWUs) – which have increased 340% since 1990. Luxembourg's agricultural workforce is roughly two percent of the nation's active population, which is one of the smallest percentages among the EU member nations.

Agricultural holdings by families in the country have declined by half over the past 25 years - from 3,770 in 1990 to 1,900 in 2015; while corporate and group holdings have increased more than 400% – from 35 to 144. Luxembourg's utilized agricultural land has remained roughly constant since 1990 at 131,000 hectares, nearly split between permanent grasslands and arable land. Half the farms are 50 hectares or more in size, covering 86% of Luxembourg's agricultural land in 2010; one-fifth of farms, comprising half of utilized agricultural area (UAA), are more than 100 ha in size.[121]

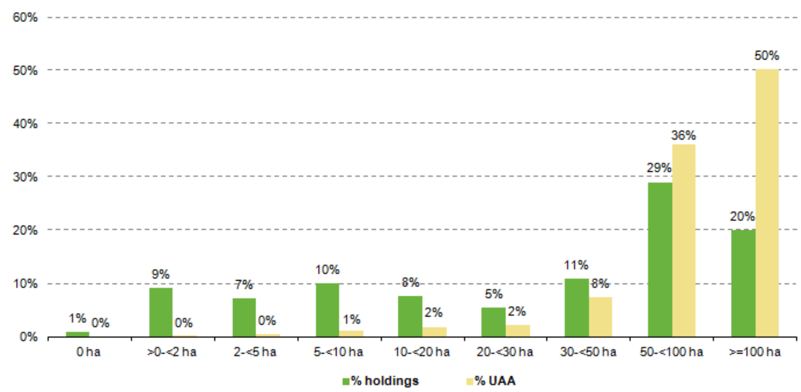
In Luxembourg, 60% of the land is rented by the farmers and only 40% is in property and the proportion of leased land is continually increasing.[122] There is a very high pressure on farmland prices because of the roaring development in the other sectors of the national economy.

[121] STATEC Farm Survey, Luxembourg.
[122] Figures for 2015; source STATEC

Moreover, due to nature and biodiversity protection regulations, commercial developers are required to offset the loss of soils and biotops due to paving. This is often done by extensification of farming land (for example, arable land is converted to extensive grassland, forest etc.), thus adding even more pressure and speculation on agricultural land.

In these circumstances, access to land becomes a difficult challenge for agricultural holdings, which cannot compete with other more profitable economic sectors.

Luxembourg Farm Holdings and Utilized Agricultural Area



Source: EuroStat (2012) Agricultural census in Luxembourg

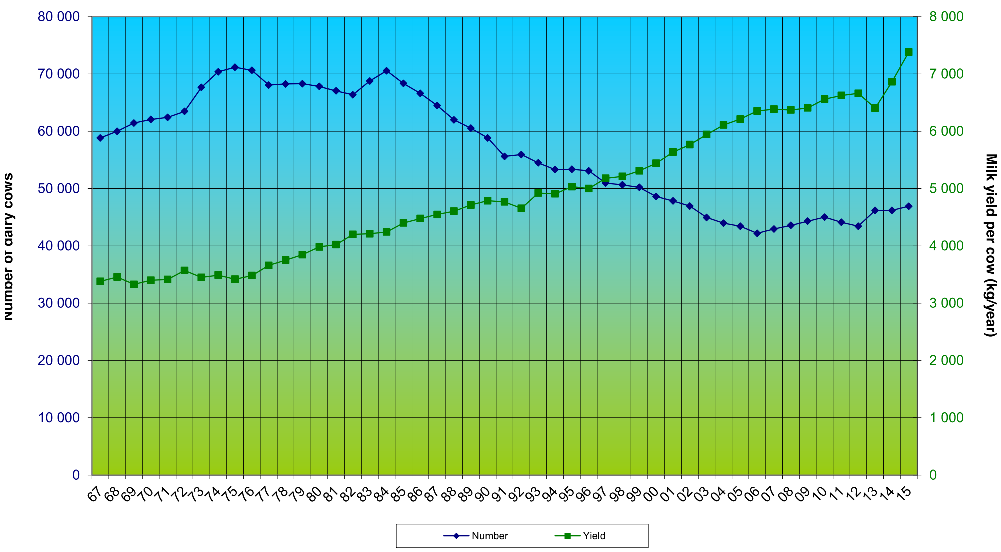
Types of farming include specialized field crops, horticulture, permanent crops, and livestock grazing. Two-thirds of the farms involve specialized livestock grazing consisting of nearly 200,000 cattle – including specialized dairy cattle (518 farms), specialized breeding and meat cattle (351 farms), and specialized dairy, breeding and meat cattle (231 farms). Other livestock include 8,700 sheep, 4,700 horses, and 4,300 goats. In addition, in 2015 farmers raised roughly 116,000 poultry and 87,000 pigs.

Intensification has been a hallmark of the dairy sector, as shown in the two graphs below. The milk yield in kilograms per cow per year has increased from 3,380 kg/cow/year in 1967 to 7,382 kg/cow/year in 2015, or a 220% increase, as well as a 175% increase in total milk production (see charts below).[123] At the same time, the number of dairy cows has declined to 46,908 in 2015 – one-third less than the high of 71,183 in 1975.[124]

[123] Luxembourg (2015) Service d'economie rurale (SER) for statistics on production of milk and milk prices and STATEC for statistics on farms with dairy cows and the number of dairy cows, Ministere de l'Agriculture.

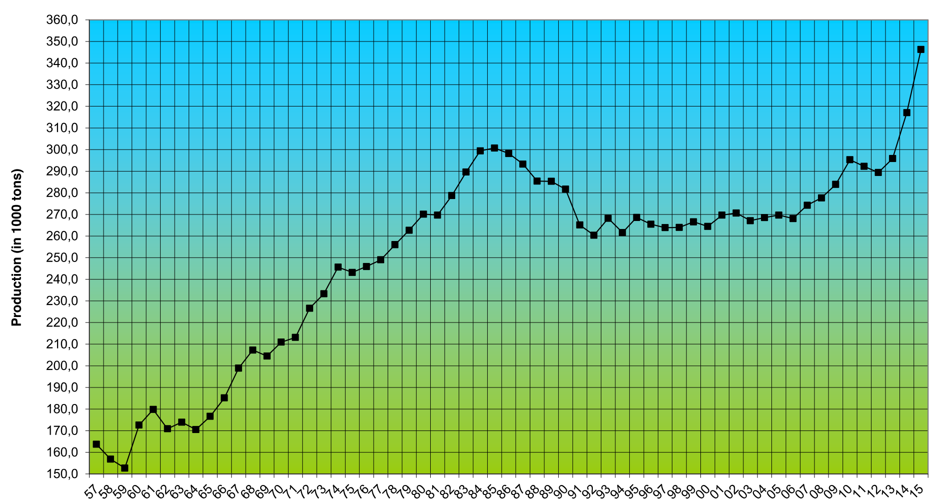
[124] *Ibid*.

Number of dairy cows and milk yield per cow in Luxembourg



Source: Luxembourg (2015) Service d'economie rurale (SER) and STATEC, Ministere de l'Agriculture

Milk Production in Luxembourg



Source: Luxembourg (2015) Service d'economie rurale (SER) and STATEC, Ministere de l'Agriculture

Sustainability Production Indicators

In line with the historical EU promotion of intensive agricultural production through the Common Agricultural Policy (CAP), the European Commission's 1999 Communication on *Directions towards sustainable agriculture* incorporated the promotion of environmentally sustainable production processes and outcomes.[125]

The emphasis has shifted from simply sustaining intensive production levels to increasing production levels that are ecologically sustainable. Achieving higher yields and value added entails more effective application of inputs while simultaneously reducing detrimental and unwanted outputs.

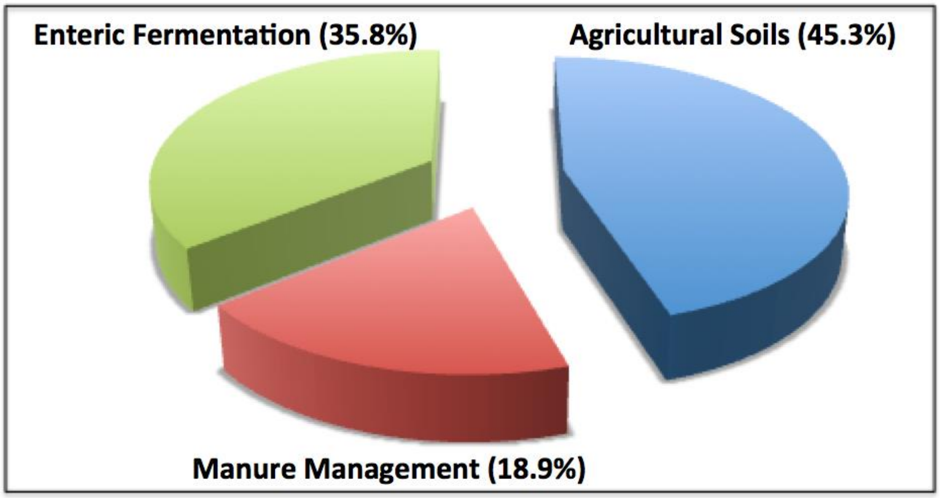
There are several sustainability indicators for assessing Luxembourg's progress in the agriculture sector. Regarding climate change, the agriculture sector was responsible for 5.65% of the nation's total GHG emissions – or approximately 614,000 metric tonnes (mt) in 2012. Emissions from agricultural soils constituted the largest fraction (45.3%, 278,000 mt), followed by enteric fermentation (35.8%, 220,000 mt) and manure management (18.9%, 116,000 mt).

Land-based CO_2-equivalent emissions were reduced through LULUCF (forestry) activities by 515,000 mt between 1990 and 2012, along with 46,000 mt reduced from grasslands during the same time period.[126] Overall, agriculture emissions declined 10.2% even while cropland expansion increased emissions by 37,000 mt. These data are shown in the three charts below.

[125] EC (1999) Communication on Directions towards sustainable agriculture, COM (1999) 22 final, January 27, 1999.
[126] LULUCF stands for Land use, land-use change and forestry.

Breakdown of Luxembourg's Agriculture sector GHG emissions

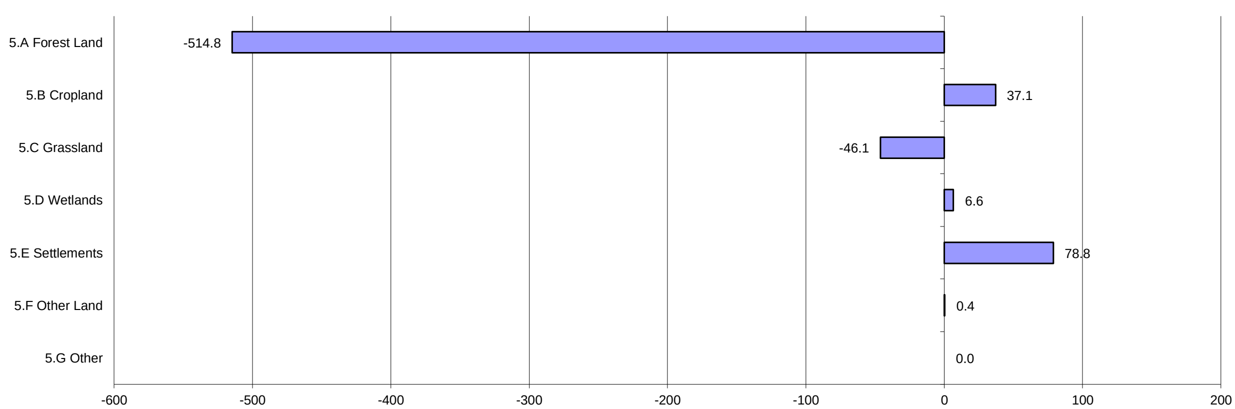
(614,000 metric tonnes in 2012)



Source: UN (2013) Summary of GHG Emissions for Luxembourg, UN Climate Change Secretariat

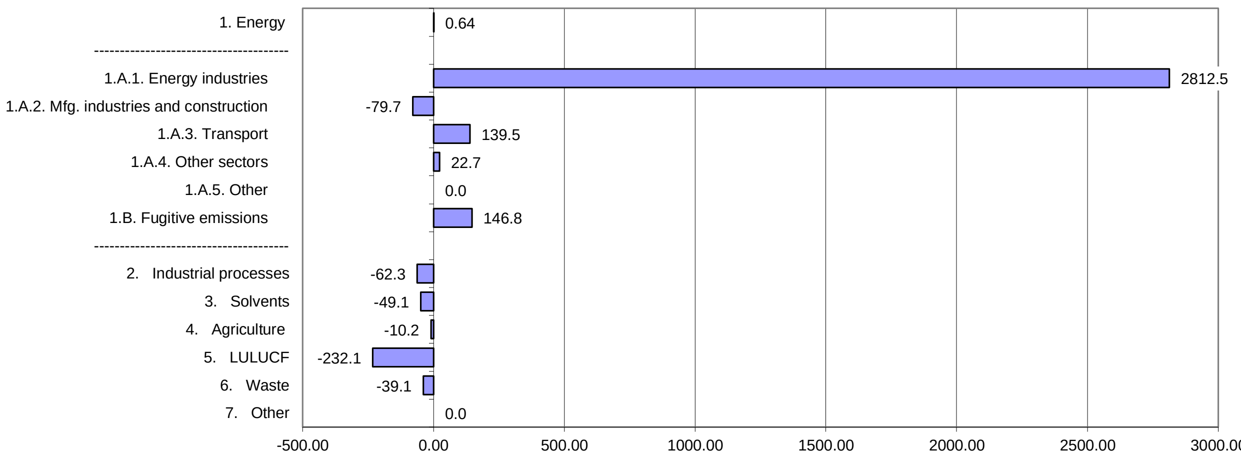
Breakdown of GHG emissions/removals within the LULUCF sector,

(Gigagrams, or thousand metric tonnes, CO_2 equivalent)



Source: UN (2013) Summary of GHG Emissions for Luxembourg, UN Climate Change Secretariat

Change in Luxembourg GHG emissions/removals from 1990 to 2012, %



Source: UN (2013) Summary of GHG Emissions for Luxembourg, UN Climate Change Secretariat

Ongoing research on the persistence and durability of soil carbon restoration indicates several factors of uncertainty. As recently summarized, "the net sequestration of GHGs by the land surface may even diminish as methane (CH_4) and nitrous oxide (N_2O) emissions increase with further intensification of agriculture and forestry."[127] Ongoing, accurate, and increasingly fine-grained measurement is imperative to provide the level of assurance that soil carbon sinks are persisting, and not becoming GHG sources over time. The Internet of Things can play a highly effective role in providing the monitoring, measurement and verification functions, from the farm field through all the steps and stages of the agriculture value chain.

In addition to GHG emissions, the agriculture sector's use of pesticides and fertilizers continues to impact the nation's water resources. The quality of two thirds of Luxembourg's groundwater was ranked unsatisfactory in 2015 according to Carole Dieschbourg, Minister of Environment.

A pesticide spill in 2014 resulted in the considerable contamination of the lake of Esch-sur Sûre, the main drinking water reservoir of the country, leading to a ban on the herbicide Metolachlor, as well as tight new restrictions on the application of the herbicide Metazachlor. Monitoring from 2008—2012 detected pesticides at 70% below ground monitoring points.

[127] Schulze ,E.D., S. Luyssaert, P. Ciais, A. Freibauer, J.A.. Janssens *et al* (2016) Importance of methane and nitrous oxide for Europe's terrestrial greenhouse-gas balance, *Nature Geoscience*, Vol. 2, December 2009, http://www.nature.com/naturegeoscience. .

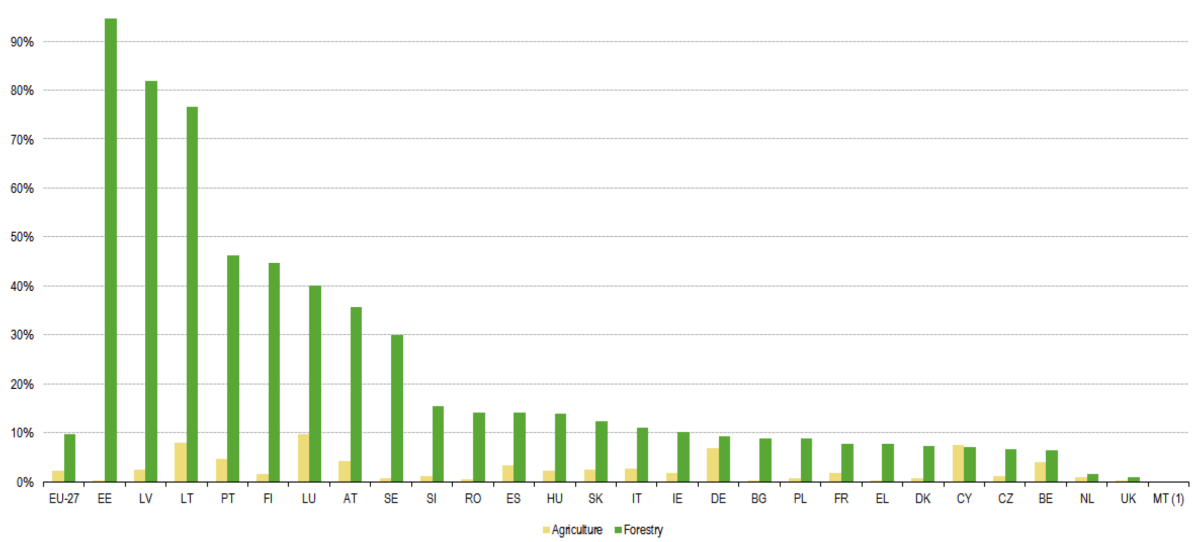
Besides pesticides, the major threat to Luxembourg's water quality is nitrate runoff. It is estimated that more than 70% of Luxembourg's surface water may not comply with the EU's 2015 targets for chemical and biological quality (EU Water Framework Directive). Roughly one-tenth of the below ground monitoring points indicated nitrates exceeded concentration limits. Luxembourg's agriculture sector does show continued progress in reducing both the total amount of fertilizer and the applications per hectare, as shown in the following chart.

Luxembourg Agriculture Consumption of mineral fertilizer, 1999-2014

	1999	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total consumption (in tons of nutritive substances)												
Nitrogenous fertilizer (N)	18 047	17 819	14 230	14 034	13 312	13 329	13 383	13 766	14 446	13 675	13 366	12 714
Phosphatic fertilizer (P2O5)	1 813	2 566	2 171	1 708	1 696	1 082	990	1 180	1 182	1 183	1 179	1 180
Potassic fertilizer (K2O)	3 019	2 898	2 388	1 876	1 853	1 120	735	1 049	1 182	1 315	917	1 180
Consumption per ha (in kg of nutritive substances per ha)												
Nitrogenous fertilizer (N)	141,7	139,6	110,2	108,9	101,7	102,2	102,4	105,0	110,0	104,0	102,0	97,0
Phosphatic fertilizer (P2O5)	14,2	20,1	16,8	13,3	13,0	8,3	7,6	9,0	9,0	9,0	9,0	9,0
Potassic fertilizer (K2O)	23,7	22,7	18,5	14,6	14,2	8,6	5,6	8,0	9,0	10,0	7,0	9,0

Source: Luxembourg SER (2015) Agriculture Statistics, Service d'Economie Rurale, http://www.ser.public.lu/statistics/index.html

Share of production of renewable energy from agriculture and forestry to total production of primary energy (%), 2010, EU-27



Source: Eurostat (2013)[128]

[128] Eurostat (2013) Agri-environmental indicator - renewable energy production, DG Agriculture and Rural Development, ePURE, European Biodiesel Board (EBB), EurObservER, Eurostat Energy Statistics,

Farmers Harvesting Higher Value-Added Renewable

Luxembourg's agriculture will never meet the profitability of other more favored territories, at least in comparison to regions where production standards are not as high as in Europe. Luxembourg's farmers complain about low incomes, and they are not and never will become competitive to supply international markets. Sustainable food will increase their margins by up to 100% (conventional milk: €0.30 /liter; organic milk: €0.50 /liter).

The net income of farmers is lower than the compensatory payments (e.g. farmers destroy public money as well as environmental goods). This is true for conventional farms and for organic farms, except for fruit, vegetable, and wine production. This raises the key question of how to diversify farmer income through viable innovative options that the farm sector could pursue to generate other secure sources of sustainable revenues while at the same time practicing ecologically sustainable farming practices.

Shifting Luxembourg to renewable energy resources is a promising option. The nation is completely dependent on several billion euros of imported oil and natural gas, and a large percentage of imported electricity. There are competitive domestic alternative options that can displace these imports within the next several decades. For Luxembourg's farming community, the alternatives offer a secure, long-term, safe and sustainable source of revenues. These revenues could alleviate, if not entirely eliminate, the fragile economic conditions many in the farming community have faced for years. This value-added opportunity extends far beyond providing a strong financial foundation for the nation's farming community, by also accruing robust climate mitigation and adaptation benefits.

Climate change is already being felt in Luxembourg and throughout Europe. Current climate change measurements in crop yields in Luxembourg find an ongoing decrease in total vegetal food production of -5.8% for 2013/2014 and - 18.9% for 2015 compared to 2013. Current weather statistics show a **40 – 50%** deficit in rain during the spring and summer. The cumulated summer rainfall [for 2015] was 136.9 liters per m2, with a 39% decrease compared to the 1981-2010 reference long term period. Rain collected for June was 39.3 l/m2, and July was 28.3 liters per/m2, the 9th driest month of July ever recorded at the Findel weather station. The cumulated rain for the 2015 spring season was only 109.3 l/m2, nearly half (47%) the expected rain for spring (1981-2010 levels averaged 206 l/m2).[129]

http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_renewable_energy_production.

[129] "Information on the climate in Luxembourg in 2015," *MeteoLux*, 15 January 2016.

Table: Monthly annual precipitation amount (mm) as well as anomalies (mm) relative to the WMO normal period from 1961-1990 at Luxembourg / Findel in 2015. Observational days for precipitation are based on daily sums between 06 UTC and 06 UTC of the following day.

2015	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation amount (mm)	70	43	37	48	24	39	28	69	122	26	68	30	604
Normals (1961-1990)	71	62	70	61	81	82	68	72	70	75	83	80	875
Anomalies (mm)	-1	-19	-33	-13	-57	-43	-40	-3	52	-49	-15	-50	-271

Source: *MeteoLux*

On the other hand, the cumulative rain in the spring was exceptionnally high (over 300 l/m2) in 2016. This had a very negative effect on the grain and wine harvest, with a loss of yield of up to 30% and bad quality parameters.

Conservative U.S. farmers and ranchers in Kansas and other Great Plains States, who have suffered severe droughts and floods for more than a decade, now refer to wind and solar farms as their most resilient cash crops that keep on generating revenues long after crops have wilted and cattle collapsed. Solar panels and wind turbines have become the new harvesting equipment.

More importantly, solar and wind energy are generated at near zero marginal cost of production. The zero marginal cost of solar and wind energy is in stark contrast to the volatile and unpredictable price of importing fossil fuels. Moreover, solar and wind energy use nearly 100 times less water to generate electricity than fossil-fueled thermal power plants. In addition, unlike fossil fuels, solar and wind energy are non-polluting, and do not emit CO_2 and other greenhouse gas emissions, or discharge hazardous or toxic wastes during generation.

Moreover, the actual land footprints of wind turbines and solar panels are modest. More than 90% of the land area surrounding a wind turbine remains available for ongoing farming and ranching. Solar panels can be installed sufficiently high up from the ground to grow crops underneath (see photos below). It is also worth noting that compared to the land area required for wind or solar power for battery electric vehicles, the bioenergy to fuel internal combustion engine vehicles would require 30 to 60 times more area, respectively. The exergetic gains made in the solar and wind powered electrification of thermal combustion processes are significant, while also preventing the many environmental challenges and risks associated with large-scale bioenergy production, as well as the emissions and pollution resulting from fuel combustion.

The harvesting of renewable energies allows farmers a diversification of their income and to be more financially self-sufficient, providing more stability and resiliency to enable them to be more experimental. For example, they can experiment with changing crops that may be more tolerant to erratic climate and weather patterns, or crops that can be used to produce bio-based polymers for the expanding composites and 3D printing industries. The robust financial security from onsite solar and wind power systems also enable greater flexibility in implementing new smart farming methods – ICT-based precision tools and techniques – as well as eliminating petrochemical inputs through alternative methods and organic practices. Accumulating experience with smart farming approaches provides positive evidence of increasing yields while reducing operating costs.

The transition to a post-carbon (emissions), biologique, organic, and ecologically sustainable agriculture establishes a new era of best practices that can position Luxembourg agricultural products as a premier global brand noteworthy for the care, stewardship, and regenerative approach to farming that results in healthy, nourishing, and safe products that citizens can trust and prefer. The ecological brand goes hand-in-hand with obtaining a premium price for Luxembourg agricultural products.

There are far more benefits to be garnered, societal-wide. Farmers can lead the way to weaning the national economy off its nearly 100% dependency on imported oil and natural gas, and the more than 50% of its electricity that is imported. The several billion dollars now exported for fuel will remain in the domestic economy, circulating many-fold in local businesses and employment.

Farmers will also be at the forefront of significantly reducing the high level of CO_2 emissions and other pollutants towards zero. Luxembourg's per capita CO_2 emission levels are more than twice as high as the EU average.

Moreover, the Luxembourg government's strong promotion of ICT innovations through advanced research centers collaborating with business firms - innovations ranging across High Performance Computing (HPC), Big Data Analytics (BDA), high-speed Internet connectivity, computational visualization, geoinformatics, smart wireless sensor networks, Blockchain distributed ledger technology, and more – all have great relevance in the designing, siting, engineering, constructing, operating, and blockchaining of the electricity and monetary transactions between farmers, transmission companies, and consumers.

In addition to advancing the nation's lofty aspirations of achieving deep reductions in GHG emissions, and scaling up the nation's renewable energy resources, this transition will also further Luxembourg's ambition to become a flagship circular economy.

The 2015 workshop, 'Opportunities for Agriculture and Forestry in the Circular Economy,' conducted by the European Innovation Partnership for agricultural productivity and sustainability (EIP-AGRI), identified the following actions for initiating local initiatives:

1. Develop a shared vision. The stakeholders' vision should be designed for the locality and region, with a long-term profitability and sustainability focus. Lay out and communicate the project's purpose, objectives, scope and scale.

2. Develop a feasibility plan. To involve and engage key stakeholders, highlight the range of opportunities, benefits, and outputs of this alternative approach.

3. Set up a collaborative innovation network (COIN). An Internet networking platform is key for bringing together the diversity of actors to interact, enabling them to participate, ask questions, and access shared and distributed information.

4. Ensure initial investment. Financial resources are essential for scaling up new initiatives, which can take the form of financing, investment, grants, and guarantees. This requires administrative and political support from local, national and regional entities.

5. Harmonize and clarify standards. Some existing standards may impede or prohibit circular economy opportunities, such as employing certain waste streams for a variety of uses.

In gaining domestic market experience and accruing performance gains from learning curves throughout the renewable energy supply chain and value net, Luxembourg opens up additional business opportunities to export this model to other regions. The global market for wind and solar power systems is vast, enabling early movers to gain a competitive edge. In the case of Luxembourg, the combination of large industrial players, a strong financial sector, and a growing ICT sector affords the business community the wherewithal to create a comprehensive package of Knowledge-as-a-Service combined with financing, expertise and products.

Perhaps one of the most desirous qualities of this Knowledge-as-a-Service transition "package" is its numerous future proofing dimensions, some already noted. The transition to a smart agricultural economy strengthens the resilience and anti-fragile attributes of the nation's energy system against disruptions, whether due to nature, technical failure, human error, or terrorist attacks.

With all of these compelling reasons for pursuing a farm-based solar and wind "cash crop" energy system, just how large is the actual potential in Luxembourg? Several Luxembourg energy assessments have been performed in recent years. Energy production on agricultural lands presents an important value added dynamic to a hard-pressed farm community. Importing foreign energy and power resources could, perhaps, offer short-term, lower cost services, but accrue no long-term benefits to the farming community. The decision to employ solar and wind generating energy technologies on agricultural lands is, to some extent, a public policy issue, and the facts and figures in this paper are intended to inform this decision-making process.

To illustrate the opportunities specifically in Luxembourg we draw from the nation-by-nation global 100% renewable energy assessment published in December 2015, undertaken by a joint team of Stanford University and UC Berkeley research scientists, engineers and economists.[130] These figures should be seen as illuminating the opportunities, rather than precise recommendations. For example, it's possible to have more wind and less solar.

The global assessment projects energy growth out to 2050, and assumes the typical economic growth rate of business-as-usual energy studies. The assessment also postulates the electrification of all energy services capable of shifting from thermal combustion processes, as in the case of electric vehicles, space heating systems, and some industrial processes. Renewable powered hydrogen fuel production is assumed where electric conversion is not feasible.

The Stanford/UC Berkeley team estimates 22% of Luxembourg's total energy needs can be satisfied with land-based wind power. This represents 1/12th (8.6%) of the technical potential. It amounts to roughly 1,600 MW (nameplate capacity). That would require 319 installed turbines each 5 MW rated power, and assuming 43% average capacity factor.

The land spacing area for turbines would span 202 km2 (20,200 hectares, or 7.8% of land area), although 90% of this land area would still be available for farming or ranching. For context, this is comparable to one-third of the nation's permanent grasslands. The projected levelized cost of electricity (LCOE) is €cents 7/kWh. The upfront capital costs would amount to €1.89 billion (in 2016€). The energy simple payback is 4.3 years, and if the prevention of air pollution and CO_2 prevention are included, the simple payback shrinks to 1.6 years. Roughly 260 construction jobs would be created, full-time equivalent (FTE) to build capacity, and 567 permanent operations jobs created.

[130] *Ibid*., Jacobson, Mark and Mark Delucchi *et al*. (2015).

Photo: The German company Enercon's gearless 7.5 MW wind turbine (Enercon E-126), has been operating worldwide since 2007; it is 50% larger than the 5 MW average size wind turbine used in estimating Luxembourg's wind opportunities. The Enercon E-126 hub's height is 135 meters, with a diameter rotor of 127 meters, encompassing a swept area of nearly 13,000 square meters. The 11 turbines of the Estinnes 82.5 MW wind farm in Wallonia, Belgium, are shown above.

Fraunhofer LuxRes 2007 (Wind Power) Update report (June 2016)

How does the Stanford/UC Berkeley wind power assessment compare with and differ from a Fraunhofer Institute June 2016 report updating the LuxRes 2007 report?[131] The key difference is the time frame, with Fraunhofer focused on 2020, compared to 2050 by the Stanford/UC Berkeley (S/UCB) analysis. The second key difference is capacity factor. While both reports assume 5 MW turbine sizes, Fraunhofer conservatively assumes 23% capacity factor by 2020, and S/UCB assumes 43% achieved by 2050. Capacity factors in the 40 to 50 percent range already occur with increasing frequency in new installations in good wind sites.[132] Fraunhofer estimates technical potential at 5,700 GWh per year, or 28% of their theoretical potential estimate of 20,500 GWh per year; which compares with the S/UCB estimate of 5,900 GWh achievable by 2050, or 8% of the their theoretical potential estimate of 70,000+ GWH per year. Differences in theoretical potential would require a separate study, but appear to be due to different capacity factor assumptions, turbine spacing arrangements, possible differences in assumptions about land availability, wind speeds and durations, plus other potential factors

The Stanford/UC Berkeley team estimates 67.3% of Luxembourg's total energy needs can be satisfied with utility-scale Solar PV systems. This presents 99.6% of technical potential, amounting to 14,400 MW (nameplate capacity). Roughly 287 solar farms would be needed,

[131] Fraunhofer (2016) Aktualisierung der Potenzialanalyse für erneuerbare Energien in Luxemburg (Update Analysis of Potential for Renewable Energies in Luxembourg), by Mario Ragwitz, Felix Reitze & Michael Schön, Fraunhofer Institute Systems and Innovation Research (Fh-ISI) Institute for Resource Efficiency and Energy Strategies (IREES GmbH), June 08, 2016.

[132] Shahan, Zachary (2012) Wind Turbine Net Capacity Factor — 50% the New Normal? *Clean Technica*, July 27, 2012, http://cleantechnica.com/2012/07/27/wind-turbine-net-capacity-factor-50-the-new-normal/.

each 50 MW of rated power, operating at 14.6% average capacity factors. The land footprint would require an area of 129 km2 (12,900 hectares, or 4.96% land area). For context, the area is comparable to 20% of arable land. Most of this land could be available under the solar panels for vegetable cultivation. The LCOE is estimated at €cents 9/kWh, with upfront capital cost of €20.5 billion (in 2016€). Roughly 7,500 construction jobs would be created, full-time equivalent (FTE) to build capacity, and 11,100 permanent operations jobs created.

Fraunhofer LuxRes 2007 (Solar PV) Update report (June 2016)

How does the Stanford/UC Berkeley solar photovoltaic power assessment compare with and differ from Fraunhofer Institute's June 2016 report updating the LuxRes 2007 report?[133] As with wind power, the key difference is the time frame, with Fraunhofer focused on 2020, compared to 2050 by the S/UCB analysis. Capacity factors are roughly the same in both reports (15% by Fraunhofer, and 14.6% by S/UCB). A third key difference is the estimated technical and theoretical potentials of Luxembourg's solar PV availability. Fraunhofer calculates a technical potential of 7,900 GWh per year out of a theoretical potential of 33,200 GWh per year; whereas S/UCB calculates a technical potential of 14,400 GWh per year.

Farmers typically receive annual royalty fees for allowing siting of wind turbines. It is impossible to speculate on Luxembourg's local arrangement, but according to farmers' experience in the United States, the rural wind advocacy group, Windustry, notes, "Wind lease terms vary quite a bit, but the general rules of thumb is: 3,500 to 7,000 euros per turbine, 2,700 to 3,500 euros per megawatt of capacity, or 2-4% of gross revenues. Larger turbines should translate to larger payments. Compensation packages typically are offered as fixed yearly payments, as percentages of gross revenues, or some combination."[134]

Forming a farmers' energy cooperative to facilitate expansion of farm-based solar and wind farms is another potential option, and has already been implemented in Luxembourg in the biogas sector for more than 10 years. Agricultural cooperatives have a long history in Luxembourg.[135] University of Luxembourg Law Professor David Hiez has written extensively on the status of cooperatives in Luxembourg, and might be one expert to call upon for insights.[136][137]

[133] *Op cit*., Fraunhofer (2016).
[134] Windustry (n.d.) How Much do Farmers get paid to host wind turbines? http://www.windustry.org/about.
[135] Cogeca (2015) *Development of Agricultural Cooperatives in the EU 2014*, European agri-cooperatives, February 2015, http://www.copa-cogeca.eu/Cogeca.
[136] Hiez, David and Willy Tadjudje (2012) *Support for Farmers' Cooperatives; Country Report Luxembourg*. Wageningen: Wageningen UR.
[137] Hiez, David (2013) *Coopératives : Création, organisation, fonctionnement*, Dalloz-Sirey.

Cooperatives focused on creating wealth in and among the community (in sharp contrast to some so-called sharing activities that are actually wealth extracting from the community) are integral parts of promoting the Sharing Economy. As noted by transaction attorney Janelle Orsi, Co-founder and Executive Director of the Sustainable Economies Law Center,

> "The world's economic and ecological meltdowns demand that we now redesign our livelihoods, our enterprises, our communities, our organizations, our food system, our housing, and much more. This glorious reinvention has already begun, and many refer to it as the 'sharing economy,' the 'relationship economy,' the 'cooperative economy,' the 'grassroots economy,' or just the 'new economy.'"[138]

Smart Farming & Internet of AgriFood Value Chain

As noted above, establishing a sustainable source of revenues for farmers through onsite wind and solar power systems provides them with the flexibility and resilience to adopt ICT-based smart farming and precision agriculture technologies. The Food Working Group makes argues for greater use of the myriad smart farming tools and intelligent agriculture technologies that have emerged. The current market is roughly €3 billion and projected to double within the next five years.[139] The proliferation of wireless smart sensor networks, telematics, geoinformatics, computational visualization, Big Data analytics, drones, robotics, and other automated tools, apps, and smart algorithms, are being combined for tracking data throughout the entire farming operation - soil, plant, and animal conditions – and transporting products from "field to fork," while giving this information on-demand in real-time to farmers via their smart phones or computers. These are labor-saving, resource-conserving, cost-minimizing, and value-adding opportunities.

[138] Orsi, Janelle (2012) *Practicing Law in the Sharing Economy: Helping People Build Cooperatives, Social Enterprise, and Local Sustainable Economies*. American Bar Association.

[139] Roland Berger (2015) Precision farming: Global market volume for smart agriculture applications to grow 12 percent per year through 2020, August 2015, http://www.rolandberger.com/press_releases/515-press_archive2015_sc_content/market_for_smart_agriculture_applications_growing.html.

Illustrative example of a meat supply chain (source: GS1)

Precision agriculture aims to optimise the yield per unit of farming land based on observing, measuring and responding to inter and intra-field variability in crops. Precision agriculture makes use of a range of technologies that include GPS services, sensors and Big Data to optimize crop yields.

Rather than replace farmer expertise and instinct, ICT-based decision support systems, backed up by real time data, can provide additional information concerning all aspects of farming at a level of granularity not previously possible. This enables better decisions to be made, resulting in less waste and maximum efficiency in operations.

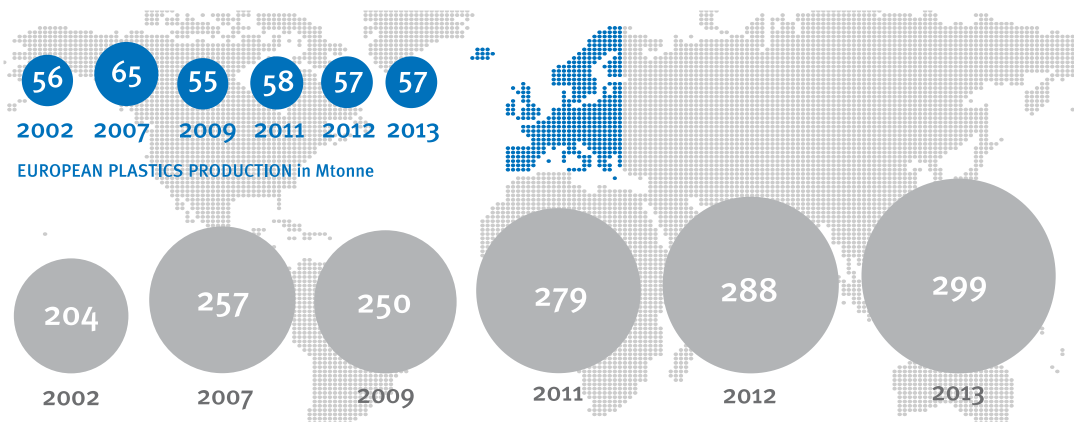
The disciplines and skills now required for agriculture include robotics, computer-based imaging, GPS technology, science-based solutions, climate forecasting, technological solutions, environmental controls and more. To make the best use of all these technologies, it is essential to train farmers and farm managers in their use.

Biofeedstocks for Bioplastics

Europe produced 57 million tonnes of plastics in 2013, with the majority (39%) being used in the packaging sector. The EU2020 has set a target of 10% of market plastics being bioplastics.

The European Bioplastics association estimated 1.7 million tonnes of bioplastics were produced in 2014 worldwide on 680,000 hectares of land, suggesting an average yield of 2.5 tonnes of bioplastics per hectare.[140] Bioplastics production is projected to increase four-fold by 2020 worldwide.[141]

Global and Europe Plastics production trends 2002-2013



Source: Plastics Europe (2014)[142]

As immense as the growth in plastics has been over the past several decades, the projected expansion over the decades to come remains significant. If expanding in the traditional linear economy fashion of "take-make-dispose" then the amount of oil consumed will increase more than 300 percent, the plastics share of CO_2 emissions will increase 15-fold, and the plastics disposed into the ocean will result in plastic waste exceeding fish in weight![143] In sharp

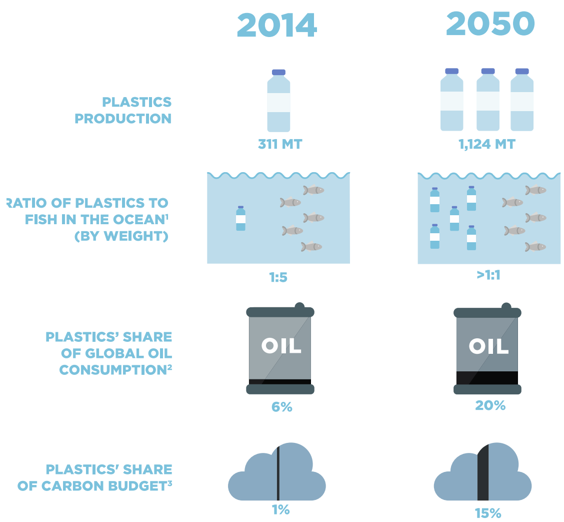
[140] European Bioplastics (2016) Renewable Feedstock, http://www.european-bioplastics.org/bioplastics/feedstock/.

[141] Whitworth, Joe (2014) Bioplastics market will grow by more than 400% by 2018, Bakery and Snacks news, December 03, 2014, http://www.bakeryandsnacks.com/Processing-Packaging/Asia-will-expand-role-in-Bioplastics-growth.

[142] Plastics Europe (2015) Plastics – the Facts 2014/2015, An analysis of European plastics production, demand and waste data,

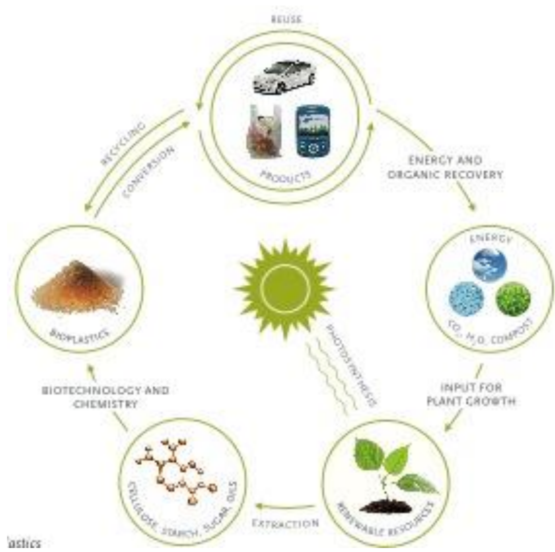
[143] WEF/EMF/MCBE (2015) *The New Plastics Economy, Rethinking the future of plastics*, World Economic Forum in collaboration with the Ellen MacArthur Foundation and McKinsey Center for Business and Environment, January 2016.

contrast, shifting to bioplastics cultivated from ecologically sustainable agricultural practices would lead to a circular economy of wastes serving as nutrients and the process going from cradle to cradle.



Source: WEF/EMF/MCBE (2016)

When not competing with food and livestock production for land and crops, bioplastics are considered an integral part of growing a circular economy.

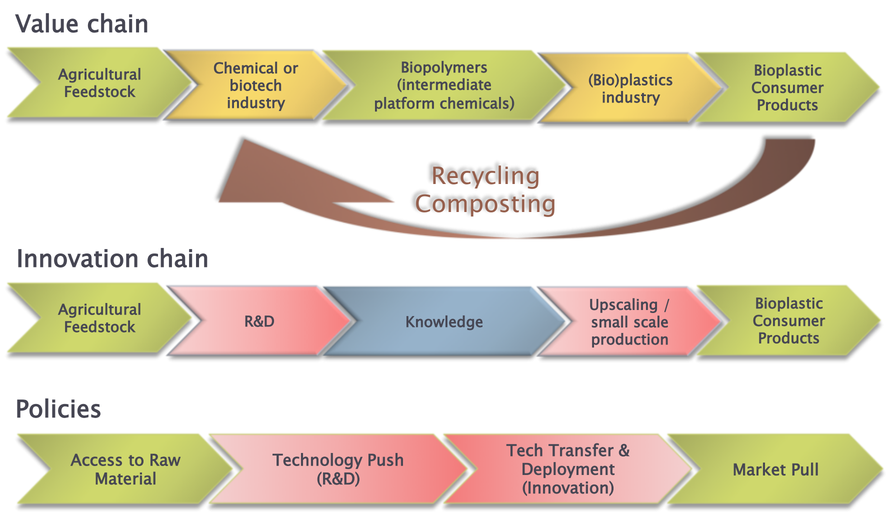


Source: European Bioplastics (2016)[144]

[144] European Bioplastics (2016) Biobased plastics – fostering a resource efficient circular economy, Benefits, feedstock types, sustainable sourcing, land use, www.plasticseurope.org.

Luxembourg's agriculture sector has the great advantages of outstanding research institutes in composite plastics, as well as world leading corporations on composite materials. One of the areas worthy of additional research and analysis is to determine the value-add to farmers of cultivating feedstock and or gathering a percentage of residues for use in the bioplastic materials industry.

The Bioplastics Value and Innovation Chain



Source: Carrez, Dirk (2011) [145]

Preventing, Reducing, Reusing Food Wastes

According to data compiled by the European Economic and Social Committee in 2013, 89 million tonnes of food waste is generated annually in the EU27 (Croatia was not included in this study), amounting to 179 kg per capita. By 2020 this sum could increase to 126 million tonnes if no further efforts are taken, raising CO_2 emissions to 170 million tonnes per annum, or 3% of all EU27 GHG emissions.[146]

The issue of food waste in Luxembourg was examined in the study "Emergence, treatment and prevention of food waste in the Grand Duchy of Luxembourg." This study is based on data evaluation of environmental management and other information that have been identified within a set of surveys of different actors in the food sector. A total of 74 surveys were sent to food trades, catering and kitchens enterprises, among which there were 57 answers. The

[145] Carrez, Dirk (2011) European policies impacting bioplastics, An Assessment, Clever Consult bvba, European Bioplastics Conference Berlin, 22-23 November 2011.

[146] EU EESC (2013) Prevention and reduction of food waste, References: NAT/570 EESC-2012-1917, European Economic and Social Committee, March 20, 2013, http://www.eesc.europa.eu/?i=portal.en.nat-opinions.25955.

Luxembourgish total volume of food waste is estimated to 68,010 tonnes yearly, which amounts to 123.7 kg / inhabitant per year. Within this total, 31,005 tonnes are avoidable food waste, which amounts to 56.4 kg / inhabitant per year.

In addition to food wastes, there are organic quantities of bio-refuse. Since Luxembourg's 1994 inclusion of organic waste separation requirement, the collection of organic quantities of waste and bio-refuse increased ten-fold (by 2012 as shown in this chart). Of the roughly 97,000 tonnes per year, Luxembourg landfills 7%, incinerates 52% and biologically treats 41%, including composting and anaerobic digestion (based on 2004 data of food and green waste management, so percentages may be different as of 2016).[147]

LU accepted organic quantities of waste and bio-refuse (in tons) 2004 -2012

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012
Specification									
Composting installations	51,692	54,817	57,242	58,196	59,628	63,866	62,202	47,798	54,109
MINETT-Kompost Mondercange	27,514	28,746	28,743	30,173	30,614	32,237	30,868	29,977	32,411
SICA Mamer	4,899	5,278	5,061	5,185	5,117	5,288	5,315	.	.
SIDEC Fridhaff	6,564	6,510	6,238	6,092	5,678	5,989	5,392	5,343	6,391
SIDEC Angelsberg	2,534	2,651	2,670	2,702	1,917	2,219	1,784	1,815	2,491
Commune of Hesperange	742	786	743	786	830	743	682	836	862
Luxembourg-city/Reckenthal	9,439	8,083	11,108	9,733	11,921	12,187	13,767	.	.
SIGRE Muertendall	.	2,763	2,679	3,525	3,551	5,203	4,394	9,826	11,953
Pétange	.	.	.	.	.	.	.	.	.
Installations of cofermentation	5,471	5,826	12,277	11,981	14,849	21,596	26,945	35,726	39,045
Exports	3,035	715	1,805	4,514	1,173	600	1,261	3,248	775

Source: Statistics Portal Grand Duchy of Luxembourg, November 19, 2014,

According to a World Bank assessment, organic wastes worldwide amounted to roughly 600 million tonnes in 2012, with projected doubling by 2025 and disposal costs rising to one-third of a trillion euros.[148] As part of the EU's PLASCARB collaborative, ongoing research, development

[147] JRC (2008) *Inventory of Existing Studies Applying Life Cycle Thinking to Bio waste Management* (Analysis of Existing Studies that Use a Life Cycle Approach to Assess the Environmental Performance of Different Options for the Management of the Organic Fraction of Municipal Solid Waste), EUR 23497.

[148] World Bank (2012) *WHAT A WASTE, A Global Review of Solid Waste Management*, prepared by Daniel Hoornweg and Perinaz Bhada-Tata, March 2012, No. 15, World Bank Urban Development series,

and innovation (RDI) is focused on advanced technologies like microwave plasma for transforming organic quantities of wastes and bio-refuse into biogas, high value carbon graphite, and renewable hydrogen. PLASCARB explains the microwave plasma process:

"Molecular cleavage using plasma is well known. This microwave plasma technology involves microwave induced plasma to energy efficiently cleave CH4 [methane] into graphitic carbon and hydrogen, with no CO_2 emissions. The process uses non-equilibrium (or 'cold') plasma induced by microwave energy from magnetrons. Microwaves provide a unique means of efficiently transferring energy directly into the electron bonds in gas molecules. In this non-equilibrium plasma, ionisation and chemical processes are directly determined by electron temperatures, and therefore not as sensitive to thermal processes and the gas ion temperature as thermal plasma. This enables increased energy efficiency, milder process conditions and reduced process complexity. The key element of innovation is the generation of large homogeneous non-equilibrium plasma zones for cracking methane into valuable carbon products at atmospheric pressure with potential for industrial scale operation."[149]

It is unknown as to when the promising ultra-high-efficiency, ultra-low emission microwave plasma technology will become commercially available and competitive with existing and other new innovative waste conversion technologies. More immediately, it is worth exploring the application of ICT/IoT technologies to enhance tracking these material flows, and determining which of the separated food wastes can be soil composted rather than incinerated or land-filled.

ORGANIC WASTE & BIO-REFUSE DEFINITIONS

"Food waste can be defined as avoidable (e.g. left overs on a plate), partly avoidable (depends on the personal habits of the consumer, e.g. skin of an apple) and not avoidable fractions (e.g. bones). In order to have a clearer opinion on waste types it is important to define the differences between food waste, organic waste, biodegradable waste and bio-waste.

Food waste: Food waste or food loss is food that is discarded or cannot be used.

Organic waste: Organic waste is anything that comes from plants or animals that is biodegradable

http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTURBANDEVELOPMENT/0,,contentMDK:23172887~pagePK:210058~piPK:210062~theSitePK:337178,00.html.

[149] PLASCARB (2016) Microwave Plasma, http://www.plascarb.eu/microwave_plasma.

Biodegradable waste: Biodegradable waste is defined as any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard

Bio-waste: biodegradable garden and park waste, biodegradable food and kitchen waste from households, restaurants, caterers and retail premises and biodegradable comparable waste from food processing plants."

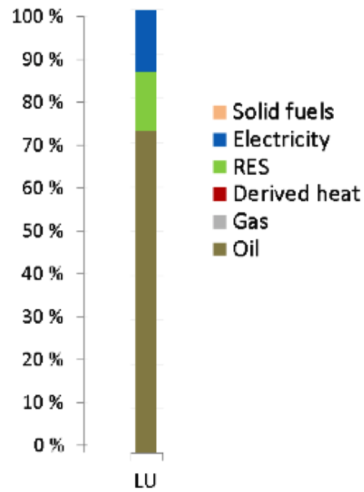
Source: PLASCARB (2015)[150]

Conversion of Fossil-Fueled to Electric-Powered Farm Equipment

Farms are heavily dependent on fossil fuels for equipment to perform a range of operations. Oil and gas fuel more than 70% of Luxembourg's farm sector. Energy efficiency gains have been beneficial in reducing direct energy used in agriculture throughout the EU by 1% per hectare per annum. Roughly 135 kg of oil equivalent were directly consumed per hectare in 2010, and inclusion of the indirect energy use (e.g., fertilizer and pesticides) increased this amount by several fold.[151]

[150] PLASCARB (2015) *Report about Food Waste Statistics in Europe*, PLASCARB Innovative plasma based transformation of food waste into high value graphitic carbon and renewable hydrogen, by Daniel Frohnmaier, Peter Brandstetter and Florian Gehring, 7th Framework Programme for research, technological development and demonstration under grant agreement No 603488

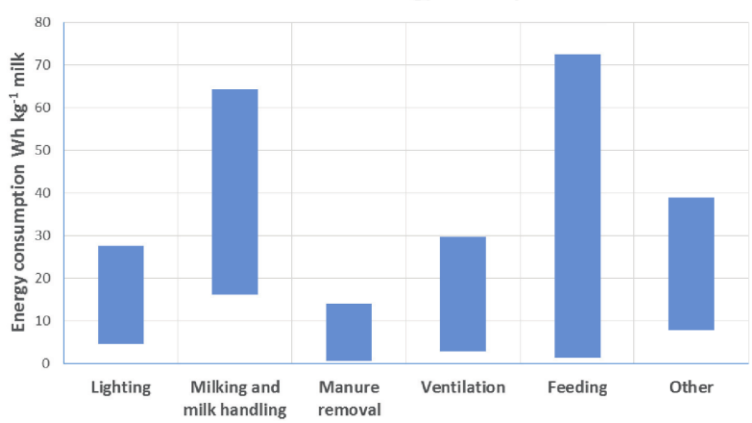
[151] EC JRC (2015) *Energy use in the EU food sector: State of play and opportunities for improvement*, by F. Monforti-Ferrario, J.-F. Dallemand, I. Pinedo Pascua, V. Motola, *et al*., Report EUR 27247, European Commission, Joint Research Centre, Institute for Energy and Transport and Institute for Environment and Sustainability, https://ec.europa.eu/energy/en/news/sustainable-energy-use-eu-food-sector-%E2%80%93-jrc-study.



Source: EC JRC (2015) Luxembourg energy types.

Energy efficiency-productivity improvements are site-specific, with wide variation in the energy consumed per type of delivered energy service. For example, the following chart shows the variation in direct energy consumption of dairy milk production. A professional audit can determine if additional efficiency gains can be achieved cost-effectively. Implementation of wireless smart sensor networks providing real-time data to develop intelligent algorithms and smart analytic applications will enable designing for and maintaining optimal energy performance of each energy-consuming piece of machinery or device.

Variations in Direct Energy Consumption



Source: Rajaniemi et al. (2016)[152]

[152] Rajaniemi, M., M. Turunen and J. Ahokas (2015) Direct energy consumption and saving possibilities in milk production, *Agronomy Research* 13(1), 261–268.

John Deere's line of E tractors (“electricity”) is indicative of a shift underway in reducing fossil fuel consumption by increasing power electronics used in farm machinery. The E models generate electricity for operating the tractor’s air conditioning compressor, the air brakes compressor, fans for engine cooling, as well as powering shop and hand tools. Farm machinery has not yet experienced the inroads witnessed in electric buses, trucks and automobiles, but the spillover and crossover is under development.

Deere’s 7030E Series tractor, available for nearly a decade, has “a built-in power generator that makes 400-volt, 3-phase power and 230-volt DC power on-the-go,” and includes an “all-electric twin-disc fertilizer spreader. It uses the three-phase power to drive spreader motors, while 12 V power drives the agitators and two electric actuators. The spreader offers a clear example of the benefits of electric drives. Drive speeds are controlled independently of tractor ground speed or rpm. Speeds are easy to adjust and hold constant. Spinner discs can be shut down more quickly, thanks to the electrical braking of disc motors.”[153]

Electric pick-up trucks are available, ready for serving frequent farmer mobility needs, like 20 to 30 kilometer round-trips to feed and parts stores, chores around fields, going to and from grain elevators, moving loads, etc. The excellent torque of electric motors would be a benefit for hauling animals or towing trailers.

The extra weight of batteries for electric utility tractors should be less a liability than in cars, by providing some useful tractor ballast. Actions only requiring a short time, like feeding cattle twice a day with a silage loader-tractor, would be better served by an all-electric tractor, as would other jobs taking up a few hours.

The declining cost advancements in stationary battery systems are being marketed by numerous firms - Tesla’s Powerwall, Schneider Electric’s EcoBlade, Sonnenbatterie, Samsung SDI, LG Chem, Saft Groupe, and many start-ups – and bring to the farm the opportunity to integrate these advanced batteries with solar PV systems or wind turbines for reducing and replacing fossil fuel needs for lights, dryers, pumps, compressors, fans, refrigeration, coolers, etc.

Zürn Harvesting GmbH & Co. KG, the John Deere subsidiary, has developed an electrically driven header where separate electric motors individually power at variable speeds the auger, knife, reel and belt drives; while displacing sprockets, chains, pulleys and belts. The header was engineered jointly with Group Schumacher and the University of Dresden. In addition to displacing fuels and emissions, there are other benefits. For example, the “knife speed can be varied separately to the table auger and, with each of the adapted premium flow table’s rubber

[153] See: https://www.farmshow.com/a_article.php?aid=20815

belts powered by its own motor, it's now possible to reverse them or speed them up independently to clear blockages and maintain even crop flow."[154]

There is also an intelligence dimension. Sensors are embedded into each electric motor that monitors torque loading. Zürn and partners are developing smart algorithms for processing real-time data that enables maintaining the header at optimal use by varying the numerous parameters automatically.

There are other sensor and controller feedback communication features capable of performing a number of other real-time fine-tuning and optimizing adjustments.[155]

Zürn Harvesting GmbH & Co. KG, in collaboration with its partners was awarded a silver medal for the fully electrically driven i-Flow header at Agritechnica 2015.

Fuel costs can be reduced by one-fourth by using electric motors to replace hydraulics. The higher efficiency of electric drive components is one key reason why farm machinery companies are developing electrified farm equipment. A Deere engineer showcasing some of the new equipment at Agritechnica pointed out, "Mechanical and hydraulic drive units are only 65 to 70% efficient [whereas] electric motors are 90% efficient and electric power is safer and more flexible, offering better control and instant torque. It's the trend of the future."[156]

Blockchain – Monitoring and Measuring Material Flows and Building Consumer Trust

"Think about the blockchain as another class of thing, like the Internet − a comprehensive information technology with tiered technical levels and multiple classes of applications for any

[154] See: http://www.zurnuk.co.uk/wp-content/uploads/2010/12/Brochure-Premium-Flow.pdf
[155] FW (2016) The Shape of Things to Come, *Farmers Weekly*, April 11, 2016, http://farmersweekly.co.nz/article/the-shape-of-things-to-come?p=100%253Fp%253D102.
[156] Farm Show (2012) Electrification of Ag Equipment, *Farm Show* magazine, Vol 36, Issue 1, https://www.farmshow.com/a_article.php?aid=25108.

form of asset registry, inventory, and exchange, including every area of finance, economics, and money. In fact it is even more; the blockchain concept is a new organizing paradigm."[157]

Blockchain technology has emerged as a valuable transaction and activity tracking tool that can be applied all along the agricultural value chain that results in building consumer trust and confidence in the health and safety of food products.

Organic food and farming methods are critical to sustainability and the long-term health of a population. The biggest challenge that these inherently decentralized farming methods face is that they must compete with the economies-of-scale of large agribusinesses. The solution has been for organic farmers to collectivize their marketing and sales efforts to try to boost their bargaining power. However there is a fundamental problem in that large-scale buyers can't be assured that the produce coming from multiple producers is of uniform quality. The blockchain offers a potential solution as it can be used to keep track of authenticated credentials of producers, certifing that their food is organic and how it is produced. In a blockchain, a farmer is unable to alter the record inserted by whatever body is employed to periodically verify that he or she is meeting required standards. As bio-sensory technology advances, this authentication process can be increasingly automated and, therefore, will become increasingly trustworthy.

Once an agreed-upon trusted standard can be established in this manner, decentralized organic food production can be sold more like a uniform commodity. Here, the blockchain is also useful: smart contracts, transparent data and the very low transactions costs that digital money affords would allow the creation of commodity derivatives of much smaller size than the contracts that are traded in big commodity markets in Chicago and elsewhere. This is a good way to improve the position of the farmers and of their cooperatives in the foodchain, with the result of fairer trading practices and a better income for the producers. As a trading nation, it's an opportunity for Luxembourg to lead the way in setting pricing models for trade in organic, sustainably farmed food.[158]

Blockchain technology is also being used in promoting energy services from wind farms and solar PV systems, as well as a myriad of exergetic efficiency-productivity operations.

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[157] Swan, Melanie (n.d.) Institute for Blockchain Studies, http://www.blockchainstudies.org/.

[158] Agentic Group (2016) internal communication, http://www.agenticgroup.com/#about.

Increasing Biologique / Organic Products

A 2011 Regional Report on Sustainability prepared by the Lycée Technique Agricole and Dairy Management, with the support of the government of Luxembourg, provides some helpful data, even if somewhat dated (2008). One economic indicator of merit is the estimate of land productivity at 919 € Gross Value Added (GVA) per ha, presumably 2008 (but purportedly declining in recent years).

Milk is reported as Luxembourg's main farm product, comprising one-third of agricultural production's total value. At that time, there were roughly 860 milk-producing farms, accounting for two-thirds of Luxembourg's total agricultural land area. More than half of milk production is shipped out of the country. Currently, less than 1 percent of milk is organic (lait biologique), or 2,300 tonnes out of 317,000 tonnes of milk production in 2014.

Most dairy farms include arable crops and meat production. Three-fourths of dairy farms derive roughly two-thirds of their total gross product from milk. There has been a yearly decline of 3.7% in the number of dairy farms. Automatic milking is practiced by 10% of the farms and it is increasing fast.[159]

Organic Farming & Consumer-Supported Agriculture (CSA)

According to 2012 statistics from IFOAM, the organic market in Luxembourg had €75 million in retail sales. In 2013, there were 115 organic farmers in Luxembourg, operating on 4,145 hectares. There are an additional 77 processing and 5 import companies marketing organic products. All of this occurs under the 'Bio-Lëtzebuerg — Vereenegung fir Bio-Landwirtschaft Lëtzebuerg A.S.B.L. label (Union for Organic Agriculture Luxembourg).

[159] Lycée Technique Agricole (2011) *Evaluation de la durabilité régionale agricole au Luxembourg*, by Jeff Boonen et al., in collaboration with Dairy Management (Dairyman), http://www.interregdairyman.eu/en/dairyman/regions/Luxembourg.htm.

L'agriculture biologique in Luxembourg

	2009	2010	2011	2012
Producteurs	88	96	102	115
Agriculteurs	52	54	57	62
Maraîchers	12	15	14	16
Viticulteurs	5	9	8	11
Fruiticulteurs	7	6	8	8
Apiculteurs	12	12	15	16
Autres	0	0	0	2
Transformateurs	44	53	61	77
Importateurs	2	3	5	5
Surface agricole utile (ha)	3601	3731	3924	4144,5
% des exploitations agricoles	3,93	4,36	4,70	5,29
% de la surface agricole utile	2,75	2,85	2,99	3,15

Source: Plan d'action national pour la promotion de l'agriculture biologique, Communiqué – Publié le, February 20, 2013, http://www.gouvernement.lu/1795700/20-schneider?context=519177.

The nation's growth in organic products has been expanding at five to ten percent per annum in recent years, accounting for roughly 3% of agriculture production. Luxembourg reportedly has one of the highest per capita consumption rates for organic products in the world, although more than 80% of the organic products are imported.

Although there is a National Action Plan and policy support by the Ministry of Agriculture in promoting organic food research, consumer awareness, educational programs, training, and marketing support, the nation's farmers are not responding or converting to organic.

Öeko-Öeko Study of Luxembourg Organic and Conventional Farming[160]

The study compared the ecological performances and the social costs of organic and conventional farms in Luxembourg and to analyse the cost-effectiveness of payments to organic farms in Luxemburg from an agro-environmental perspective. Results show that organic farms cause substantially lower environmental impacts than their conventional counterparts.

- There is a higher nitrogen (N) eutrophication potential from conventional farms and a higher N-efficiency on organic farms (on average 189% in comparison to conventional farms)
- Organic farms have a lower energy need (on average 43% of conventional farms) and a higher energy efficiency than conventional farms (on average 150% in comparison to conventional farms)
- There are lower greenhouse gas (GHG) emissions on organic farms and organic farms have a higher GHG efficiency compared to conventional farms (on average 139%)
- Organic farms have also a higher fodder autarky than conventional farms; conventional farms have lower fodder autarky, especially protein fodder autarky and especially on dairy farms (52%)
- Organic farms have on average more diverse crop rotation (7.8 elements compared to 6 on the conventional farms)
- There was a higher biodiversity on organic farms: 28% more species on organic fields and 28% more species on intensive permanent grassland
- The habitat diversity is on average twice as high on organic farms than on conventional farms
- The species number was even on organic farms with low weed cover significantly higher
- The number of red list species was nearly twice as high on organic farms than on conventional farms (4.6 compared to 2.7)

However, these additional environmental benefits do not go along with higher public payments. On average, organic farms have a somewhat lower income (85% in comparison to conventional farms) and a somewhat lower expense (74% in comparison to conventional farms). Public payments were on average at the same level for both organic and conventional

[160] Schrader, Christian, FiBL), Adrian Müller (FiBL), Steffi Zimmer (IBLA), Raymond Aendekerk (IBLA), Rocco Lioy (CONVIS), Romain Reding (CONVIS), Steve Turmes (CONVIS), Gerard Conter (SER), Simone Adam (SER), Richard Dahlem (n&ë) und Georges Moes (n&ë) (2013) Vergleichende ökonomisch-ökologische Analyse von biologisch und konventionell wirtschaftenden Betrieben in Luxemburg („öko-öko“),Ein Projekt von **IBLA** und **FiBL /Schweiz,** in enger Zusammenarbeit mit natur & ëmwelt, Service d’Economie Rurale und CONVIS, Im Rahmen des „Aktionsplanes biologische Landwirtschaft Luxemburg” mit finanzieller Unterstützung durch das Ministère de l`Agriculture, de la Viticulture et du Développement Rural – Administration des Services Techniques de l`Agriculture, ASTA.

farms. Thus, the organic farms deliver more social and ecological performances with the same level of public payments. Overall, the agricultural policy in Luxemburg did not provide incentives for ecological friendly agricultural production in a sufficiently targeted way.

Table: Overview of the most important ecological measurements analysed on the assessed organic and conventional farms. (The values of the conventional farms are set to 100% and the values of the organic farms with respect thereto)

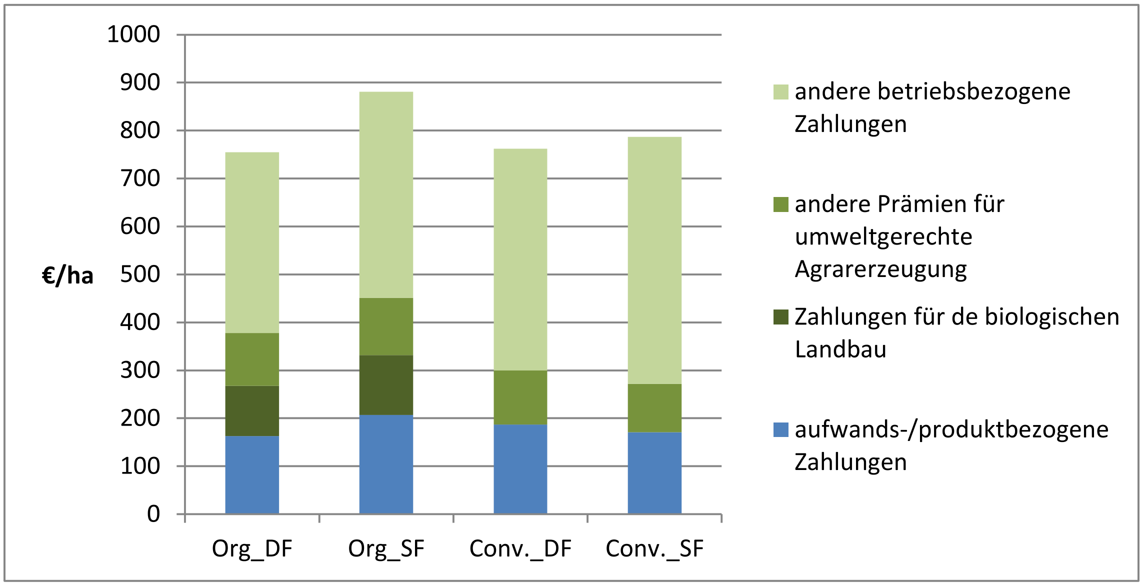
Measure	Org. values in comparison to conv.		
	Dairy farms	Suckler cow farms	all
	%	%	%
N Input (kg N/ha)	30 %	40 %	34 %
N-Output (kg N/ha)	41 %	63 %	49 %
N-Balance (kg N/ha)	26 %	32 %	28 %
N-Efficiency (€ Income/kg N)	179 %	225 %	189 %
Input fossil energy yield (GJ/ha)	38 %	54 %	43 %
Energy Output (GJ/ha)	38 %	62 %	48 %
Energy Balance (Output – Input, GJ/ha)	46 %	86 %	71 %
Energy Efficiency (€ Income/GJ Input)	145 %	168 %	150 %
Emissions from operating consumables (kg CO_2 eq.)	22 %	32 %	25 %
Emissions from animal production (kg CO_2eq.)	65 %	61 %	63 %

Emission from plant production (kg CO_2eq.)	46 %	54 %	49 %
Carbon sinks performance (C-sequestration, kg CO_2eq.)	83 %	88 %	85 %
Balance Greenhouse Gases (Emissions – Sinks, kg CO_2 eq.)	36 %	45 %	40 %
Greenhouse gas efficiency (€ Income/kg CO_2 eq.)	128 %	176 %	139 %

Table: Overview of revenues, expenses and operating results of organic and conventional farms. (The values of conventional farming methods were set at 100% and the values of organic farms with respect thereto.)

Measure	**Org. values in comparison to conv.**		
	Dairy farms	**Suckler cow farms**	**all**
	%	**%**	**%**
Operating revenue (€/ha)	70%	97 %	85 %
Operating expenses (€/ha)	68 %	86 %	74 %
Operating profit (€/ha)	94 %	118 %	104 %

Abb. 3: Overview of the average total payments, divided into operational payments (green) and expenses and product-related payments (blue) on organic and conventional farms (Org. = organic, Conv. = conventional, DF = dairy farms, SF = suckler cow farms.



Legends:

Pale green: Other premiums

Green: Premiums for agro-environmental services

Dark green: Premiums for Organic farming

Blue: Direct premiums for products (1st pillar)

DF: Dairy farms

SF: Farms with Suckler herds

One possibility that merits exploration is to work with farmers to phase in smart farming methods, which begin the process of sustainable crop and animal production while reducing the need for petrochemical inputs (fuel, fertilizers, and pesticides). Implementation of ICT-based knowledge tracking and decision support systems is integral to achieving low-input agriculture systems.

ICT-based apps and healthy food platforms can also be employed to engage more citizens in participating in Community-Supported Agriculture. This process can help persuade farmers of the market demand for healthy, safe, and nourishing food products. CSA entities currently exist in Luxembourg, but on a modest scale.

Community Gardens

The 130,000 hectares of grass and crop land to nourish 650,000 inhabitants amounts to just 0.20 ha per resident, which is one-fifth of the 0.90 ha available per world citizen: Importing alimentary goods (of all kind: cheap conventional and organic) will remain necessary in the future and initiatives like Urban Gardening, Permaculture and Aquaponic systems are highly welcome if not an absolute necessity.

The increasing concern over the impact of climate change on Luxembourg's agricultural lands requires urgent attention by the public authorities. Measures should be undertaken, allowing the agricultural sector to adapt to climate change. Improving food security includes: strengthening mainstream farming, encouraging alternatives such as organic agriculture, permaculture, urban farming and collective gardens, short-circuit distribution, alternative crops, etc.

Urban and suburban community gardens, occurring in both public spaces and on the grounds of private institutions and companies, are a well-established phenomenon worldwide. An estimated 15% to 20% of total global food production is currently grown in cities and communities. Luxembourg might take on the task of Internet mapping the nation's available community lands for expanding gardens, and making this open source platform available to citizens wanting to engage in gardening.

Given that there is wide variation in the productivity of urban farm and garden growing techniques, as well the range of practices, including or excluding the use of pesticides, the Internet platform can provide apps that effectively engage and educate citizens on how to significantly increase produce yields entirely through organic production methods.

Building on the past Century's accumulated experience worldwide with low-input, high-yield micro-farming methods, urban agriculturalists have the potential to grow, for example, complete vegetarian diets sufficient for 100 people on one hectare of land. This represents a several-fold greater yield of produce than what is grown with large-scale commercial methods.

Biointensive mini-farming techniques make it possible to grow food using three-quarters less water, 50% to 100% less fertilizer, and 99% less energy than commercial agriculture.[161] Empirical results and accumulated evidence from practitioners in more than 100 countries indicate high-yield micro- and mini-farming methods are capable of producing two to six times

[161] Jeavons, John (2010) *How to Grow More Vegetables and Fruits (and Nuts, Berries, Grains, and Other Crops) Than You Ever Thought Possible on Less Land Than You Can Imagine*, http://www.johnjeavons.info/video.html

more food, while building the soil up to 60 times faster than in nature, if properly used, and reducing by half or more the amount of land needed.[162]

School Gardens

The education system at all age levels offers a valuable focal point for engaging youth about the food system. It is a well-observed social phenomenon that young start-up enterprises are mainly comprised of youthful entrepreneurs. These savvy pioneers have been growing up with the growth of IoT technologies, social media, and collaborative innovation networks, naturally absorbing this radically new (wireless, mobile, social networking) technological infrastructure. Schools are comprised of buildings, grounds, and a flow of materials and resources that constitute learning laboratories for students to engage in applied learning experiments. Contests, software games, and the creation of apps are modes of engaging students, faculty and administrators in participating as producers, users, and prosumers.

Gaining experience in the art and practice of gardening ranks as one of the finest applied learning opportunities, opening a potentially life-long interest in healthy food cultivation, whether pursued as a career or a recreational past time.

When children start kindergarten in many parts of the world, they have their first educational experience growing and tending a small garden of plants. It is an educational tool and often a voluntary part of the elementary school curriculum. Mobile apps and Internet platforms enabling peer-to-peer interaction, and collaborative innovation initiatives, can greatly enrich this experience.

Gardens as Biological Textbooks – An Original Circular Economy

Biointensive vs Conventional

- **2 to 6 times more food produced per hectare**
- **Soil built up 60 times faster than in nature**
- **75% less water**
- **50 to 100% less fertilizer**
- **99% less petrochemical fuel**
- **Simple hand tools**

Data Source: Jeavons (2012)[163]

[162] Grow Biointensive web site, http://www.growbiointensive.org/index.html.

Significance and Value of non-traded Ecosystem Services on Farmland

While there are negative externalities – emissions and pollution – from the combustion of fossil fuels, there are also positive externalities including the ecosystem services (ES) accruing from organic farming. The economic benefits of two of these ES – biological control of pests and nitrogen mineralization – were assessed at farm scale and extrapolated to global benefits. Field experiments were conducted in New Zealand of the ES provided by non-traded non-crop species in ten organic and ten conventional arable fields. The researchers found, "The total economic value (including market and non-market components) was significantly greater in organic systems, ranging from US$ 1750–4536 per hectare per year, with US$ 1585–2560 per ha/yr in the conventional systems. The non-market component of the economic value in organic fields was also significantly higher than those in conventional fields."[164]

The most remarkable finding was the global extrapolation, "We found that the extrapolated net value of these two services provided by non-traded species could exceed the combined current global costs of pesticide and fertilizer inputs, even if utilized on only 10% of the global arable area. This approach strengthens the case for…more diversified, ES–rich, integrated agricultural systems that enhance functional agricultural biodiversity, avoid expensive inputs, minimize external costs and are less energy intensive."[165]

The authors include half a dozen caveats regarding the "what-if" global extrapolation. At the same time, one clear conclusion is to implement comparable experiments on Luxembourg fields to determine local values and benefits associated with a shift to organic farming methods.

Ecological Intensification of Forests and Woods

Promote forest permaculture in public domains as an option of forest tender contracts that involve protecting biodiversity and climate mitigation and adaptation measures. The key concept of this priority is Forest Gardens,[166] where portions of the wooded areas are designed and managed to mimic natural forests, with up to seven successive plant canopies that result in a polyculture canapy layer. The natural forest processes are used to grow food, from chestnuts

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[163] Jeavons, John (2012) *How to Grow More Vegetables and Fruits (and Nuts, Berries, Grains, and Other Crops) Than You Ever Thought Possible on Less Land Than You Can Imagine*, 8th edition, http://www.johnjeavons.info/video.html

[164] Sandhu et al. (2015), Significance and value of non-traded ecosystem services on farmland. *PeerJournal* 3:e762; DOI 10.7717/peerj.762.

[165] *Ibid.,* Sandhu et al. (2015).

[166] Forest Gardens references: http://www.greenfriends-france.org, http://www.foretscomestibles.com (Créer des jardins forêts.pdf), http://www.ecomestible.com, http://www.permaculturedesign.us, http://permafroid.blogspot.com, http://www.terra.lu.

to mushrooms and root plants. This polyculture is very productive and resilient, as the plants are associated to help one another.

Currently, Luxembourg's forests are economically under-developed assets. Climate disruption is already happening and expected to greatly amplify negative effects by 2050, threatening Luxembourg's rich biodiversity (65% of forests are protected for their biodiversity, 88% are managed). Multiple impacts are projected, including severe droughts, sudden erratic temperature shifts, soil erosion, loss of vulnerable tree species, increase of tree illnesses, loss of pollinators essential for fruit and vegetable production, and declining aesthetics that draw tourism.

PROPOSALS

1 Business Models and Innovation

1.1 Establish a public-private partnership between industries, research institutions, and key agencies at the national and local levels to develop the action map for accelerating the transition to 100% renewables.

1.2 As part of a public-private partnership to further the nation's wind and solar transition, establish an open source Geospatial Visual Mapping of all available wind and solar farm sites (e.g., http://www.awsopenwind.org/): Advanced 4D data visualization tools enable lifecycle planning that integrates siting, architectural-engineering-construction processes, virtual monitoring of performance metrics, predictive maintenance, repair and replacement procedures, and related operating data. Ongoing development and use of a suite of virtual reality tools and sensor technologies are projected to help continue reducing costs and improving performance of wind and solar PV farms. Experience gained in the application of these Internet-based tools help generate ongoing learning curves.

1.3 Set up a quadruple helix innovation network platform focused on creating an open source GPS-based inventory map of all intra urban land sites capable of growing food as well as an inventory of land sites that may need detoxification prior to being used for food production. An inventory of available land in urban and suburban areas and on rooftops in cities (a call for tenders and close collaboration with local communities is a must) is a first step in an ongoing process of informing citizens of the opportunities for engaging in local gardening and organic food production. Students and faculty can help undertake the mapping inventory as an integral part of courses, as well as coding smartphone apps to make citizens aware of nearby available sites to garden and/or where to find local organic produce grown and for sale or gleaning. Similarly, with public funding support for necessary equipment, students and faculty could perform a valuable public service by installing soil smart sensor networks to gather data for measuring and mapping the presence of any hazardous or toxic contaminants in specific locations that require remedial treatment. In addition, calculations can be performed and shared online indicating produce yields that could be achieved – per plot, by neighborhood, city wide, and nation-wide.

2 Technical

2.1 Establish a public-private working group to assess the commercial readiness for applying Ethereum and Blockchain distributed ledger technologies to supply chain transactions: a "Roadmap towards Sustainable Food Production by Transparency and Trust." These encrypted, but auditable distributed ledgers could help build transparency and trust within every supply-chain. The combination of open-source hardware and software and innovative distributed apps might transform companies' willingness and inclination to better inform their potential customers of the upstream and downstream history of their products and production processes. Features to implement overall traceability for sellers and providers might include: Origin of primary products; Labeling (origin, product number, etc.); Transport from origin to first transformation process; HACCP compatibility checks; Sales tracking; Supply-chain audit; Third Party software integration / ERP integration; Margin tracking; Customer satisfaction; Customer habits; Delivery tracking; Environmental impacts on every stage of transformation (Input-Output assessments); Contest between providers (global critical path analysis); Delta analysis (sales, margin impacts). For customers: Decentralized app using QR-codes to share information (satisfaction, point of sale, location, etc.) and check the quality of the global delivery chain (CO_2 impact, provenance, reputation of the providers, and comparison with market standards).

2.2 Establish a platform for engaging relevant professionals across sectors in identifying, prioritizing, and addressing the myriad of technical challenges associated with scaling up the IoT tools and technologies applicable to the farming community. Leverage efforts to foster the seamless interfacing with and interconnections between the Internets of Communication, Renewable Energy, and Transportation & Logistics, Buildings as nodes and nanogrids, and the Internet of Things, all of which play a vital and central role in managing, powering, and moving economic activity in the agriculture sector.

3 Regulatory

3.1 Include the monetized costs of the current unpriced externalities caused by the use of fossil fuels as an integral part of the review and revision of regulatory rules: Implement policies and procedures in the utility planning and investment decision-making process to successfully promote the transition to 100% renewable power to meet Luxembourg's energy needs. There is a substantial peer-reviewed literature that has estimated the range of unpriced social, health, and environmental costs resulting from the use of fossil fuels. There is also a wealth of assessments that have calculated the "value of solar tariffs" that encompass the societal benefits of shifting to renewables that are not currently incorporated in utility planning methodologies (which limit their analyses to just the direct costs to the utility company). The social and environmental benefits of solar, wind, and end-use efficiency improvements have been shown to significantly exceed the utility's direct benefits. Large lost opportunities continue to be incurred as a result of being ignored in making investment decisions. Including some of the monetized costs of unpriced externalities caused by fossil fuels should be used as a guiding factor in providing financial assistance to Luxembourg farmers to install wind and solar harvesting technologies across their fields.

3.2 Regulatory agencies should ensure that no regulatory barriers exist to preclude siting solar and wind technologies on farmland. The opportunities for farmers to use their land assets to secure a diversification of revenues by allowing the siting of solar and wind plants results in multiple social benefits. It builds financial resilience in Luxembourg's farming community by creating a sustainable revenue stream that can be applied to assisting farms in the transition to petrochemical-free organic farming.

3.3 Request funding sources from the EU to undertake remediation of soil contamination that currently prevents urban food production on these landscapes. Decades and centuries of industrial activity have left many community landscapes with the build-up of contaminated soils unsafe for community food production. The government agencies should request EU support to determine the best practices and procedures for remediating these soils to a point where they are safe to garden again. For example, mycology remediation has been demonstrated to achieve outstanding success in fully remediating even the most highly contaminated soils.[167,168,169] In cases where such remediation may

[167] Stamets, Paul (2005). *Mycelium Running: How Mushrooms Can Help Save the World*, http://www.fungi.com/shop/mushroom-books.html.

take years or decades to recover, alternative strategies should be tested, such as planting non-edible vegetation that helps soil carbon sequestration and regeneration, while possibly yielding aesthetic benefits (e.g., floral scapes).

4 Public Policy

4.1 Establish an ambitious set of policies, rules and regulations that align with accelerating the transition to a 100% renewable energy economy. As an integral part of revising existing regulations and implementing strong new measures, develop an action plan for engaging the farming community in recognizing the new revenue stream that can accrue through siting of wind and solar PV systems integrated with farm operations.

4.2 Undertake an inventory of the farming sector to determine current and planned uses of smart farm / precision farming / intelligent agriculture tools and technologies. The inventory should assess the time, costs and other resources required to implement and operate the equipment, and the returns on investment and time, along with performance metrics such as higher yields, labor savings, lower petrochemical or water inputs, etc. Precision agriculture aims to optimize the yield per unit of farming land based on observing, measuring and responding to inter and intra-field variability in crops. Precision agriculture makes use of a range of technologies that include GPS services, sensors, and Big Data to optimize crop yields. Rather than replace farmer expertise and gut feeling, ICT-based decision support systems, backed up by real time data, can provide additional information concerning all aspects of farming at a level of granularity not previously possible.

4.3 Promote urban organic gardening. Establish a collaborative innovation network platform that enables citizens, farmers, teachers and students, community organizations, and work locations to map the nation's available land resources where community gardens can be grown. Build out the site to include the suite of knowledge resources, tools, and apps that help citizens learn how to start and sustain high yield, low-input organic gardening practices and techniques. Use the platform to facilitate distribution of excess plants and food products for the elderly and poor. Tie in the program with local school programs,

[168] Rhodes, Christopher J. (2014) Mycoremediation (bioremediation with fungi) – growing mushrooms to clean the earth, *Chemical Speciation & Bioavailability*, 26:3, 196-198, http://dx.doi.org/10.3184/095422914X14047407349335.

[169] Bean, Laura (2014) Researcher Develops Innovative Way to Use Fungi for Bioremediation of Oil-Contaminated Soil, *EcoWatch* May 23, 2014, http://ecowatch.com/2014/05/23/mushrooms-fungi-bioremediation-contaminated-soil/.

company employee programs, and venues for under- and unemployed individuals to participate. Network with other cities to share the innovations resulting in higher participation by citizens, and greater productivity of the gardens.

4.4 **Foster entrepreneurial initiatives in local organic food production.** Several specific organizational structures and food production methods can be promoted and expanded in Luxembourg. Some of these are currently operating, like Community-Supported Agriculture (CSA) and community gardens, but could thrive if provided further support by local and national officials and agencies. Other potential systems, including hydroponics, insect[170] protein farming, eco machines[171], and vertical farming, should be assessed and tested for local viability and cost-effectiveness. To nurture suggestions, ideas, recommendations, and activities that would help scale-up local organic production and consumption, establish a collaborative innovation network (COIN) platform that enables interaction among citizens, government, academia, and businesses to determine options that could be jointly promoted. The COIN enables ongoing discussion as different recommendations go through testing and trials to see what works best, and how to modify or supersede these tests for achieving better results.

5 Financial

5.1 **Better targeting of EU and national funding sources to help the nation's farming community advance its use of smart farm techniques and technologies to enhance productivity and accelerate the transition to organic-based agriculture and livestock production.** It has to be examined why, despite relatively high support, the current level of organic food production in Luxembourg is roughly 3% – half the level of border countries like Germany.

[170] Solon, Olivia (2015) Edible Insect-Farming Hatches New Breed of 'Entopreneurs', *Bloomberg*, September 9, 2015, http://www.bloomberg.com/news/articles/2015-09-10/edible-insect-farming-hatches-new-breed-of-entopreneurs-.
[171] Todd, John (n.d.) Ecological Design, http://www.toddecological.com/index.php?id=projects

6 Educational

6.1 **Promote a collaborative innovative network (COIN) platform for farmers on how to take advantage of smart farming and precision agriculture technologies.** A COIN enables leveraging both local experience and expertise on a range of topics relevant to addressing specific farmers' questions, as well as accessing insights, applied research results, accumulated evidence and experience from professionals in the Greater Region and beyond. A COIN also provides multiple advantages over periodic classroom sessions or presentation events, including the capacity for posting queries 24/7 to a broader audience of experts, to retrieve the accumulated knowledge already shared and stored on the COIN, to access multiple learning formats (text, spreadsheets, calculators, research reports, slide presentations, audio and video clips, MOOCs, open source courses, network contacts, etc).

6.2 **Adopt an educational learning experience by providing each student with a square meter of land to nurture her/his own biological textbook during the course of the school semesters until graduating.** Gardening is at once a personal and peer collaborative experience. The process of growing ensembles of seeds into thriving gardens involves natural feedback dynamics. Students exploring and exchanging perceptions about variations in results instill a feel for the experimental processes of science: the consequences of watering too much or too little; differences in soil texture, pH levels, and nutrient content; the effects of shaded vs. sunny exposures; the applications of STEM knowledge (science, technology, engineering and mathematics); the process of composting wastes into soil amendment; as well providing students with an awareness of the range of scientific disciplines and research fields such as botany, entomology, beekeeping, pollination, climatology, microbiology, mycology, and ecology; substantially enriching their understanding and know-how of composting, soil mulching, plant grafting, seed saving and other hands-on activities. By the time they leave school, youth will have become better-informed citizens regarding food, land and agriculture issues, while having deepened their competences and broadened their horizons on a range of future opportunities, from engaging in recreational hobbies to vocational pursuit as master horticulturalists, research scientists, or professional agriculturalists.

6.3 **Expand educational opportunities and access to resources on smart agriculture applied research for students pursuing vocational tracts and related professions.** Include field research initiatives with farmers and involvement in farm operations, in addition to class instruction and online courses.

6.4 **Provide in class, online, and in field training sessions to upgrade and enhance the skills and competences of professional farmers to enable them to take advantage of intelligent agriculture techniques and technologies.** These include robotics, computer-based imaging, GPS technology, drones, climate forecasting, technological solutions, environmental controls and more. To make the best use of all these new and expanding technologies, it is essential to provide a series of ongoing trainings for farmers and farm managers to sustain productive, healthy farms.

7 Research, Development & Innovation

7.1 **Increase the engagement of farmers and farm managers in applied research with research institutes to field test practical intelligent agriculture tools and technologies.** Farmers are reluctant to change methods and adopt new technologies without clear evidence of their cost-effective practicability and minimal risk. Sharing experimental results and best practices can help identify challenges and opportunities and assist farmers in learning about the myriad of new smart technologies that can increase aggregate efficiencies and productivity while reducing marginal costs and ecological footprint.

7.2 **Increase funding support for RDI applied research on organic farming methods that could be seamlessly integrated into farm operations.** Seek out funding opportunities from EU initiatives that encompass how to detoxify soils, streams, and groundwater in making the transition to organic farming.

7.3 **Commission a University-led inventory mapping of the opportunities for increasing soil and vegetation carbon levels of Luxembourg's forests and farmlands.** Inventory mapping of carbon levels can provide a baseline for assessing both the current health and productivity of the nation's soils and vegetative landscape, as well as remaining opportunities for further enhancing carbon storage. Part of the inventory exercise should consider placement of soil smart sensor networks for gathering and monitoring data over longer time frames.

7.4 **Implement experiments on Luxembourg fields to determine local economic values and benefits from the Ecosystem Services accruing as a result of a shift to organic farming methods.** Determine the increased benefits of ecosystem services such as biological control of pests, as well as nitrogen mineralization, among others.

7.5 **Perform field tests to assess the range of benefits that can accrue from ecological intensification of forests and woods.** Undertake pilot tests in a number of locations with diverse assemblages of plants, determining the baseline for a relevant set of metrics, and monitor changes over a multi-year period, such as increased soil and vegetation carbon, moisture levels, species richness, etc. From the pilot tests, determine which ecosystems to scale up forest garden activities, while continuing to monitor long-term performance metrics.

INDUSTRY

OVERVIEW

Co-Chairs Nicolas Buck and Jérôme Merker, and the Luxembourg Industry Working Group;

Michael Totten (Assetsforlife.net), John "Skip" Laitner (Economic and Human Dimensions Research Associates), and Jeremy Rifkin, TIR Consulting Group LLC

The European Union is potentially the largest internal market in the world, with 500 million consumers, and an additional 500 million consumers in its associated partnership regions, stretching into the Mediterranean and North Africa. The build-out of an Internet of Things platform for a Third Industrial Revolution, connecting Europe and its partnership regions in a single integrated economic space, will allow business enterprises and prosumers to produce and distribute their own virtual goods and their own renewable energy, use driverless electric and fuel-cell vehicles in automated car sharing services, and manufacture an array of 3D printed products at low marginal cost in the conventional marketplace, or at near zero marginal cost in the Sharing Economy, with vast economic benefits for society.

Luxembourg hosts diverse industrial sectors including finance, logistics, chemicals, biotechnology, agriculture, steel, glass, audiovisual, crafts, and tourism. Luxembourg ranks only second to Germany among the 28 EU Member States in business innovation, making its business culture primed for leading the EU into the digital economy.

Luxembourg's leading industries will explore the vast opportunities brought on by the convergence of the Communication Internet, Renewable Energy Internet, and the automated Transportation and Logistics Internet, and the build out of an Internet of Things infrastructure. Cross-industry collaborations, the development of open-source platforms, the lateralization of value chains, collaboration between conventional market-based companies and startups in the Sharing Economy, and new distributed business models, will draw Luxembourg's industrial sectors into the emerging digital business culture. Every industry will be tasked with exploring new ways to utilize the Internet of Things to increase its aggregate efficiencies, raise productivity, reduce marginal costs, and lower its ecological footprint in a smart green Luxembourg.

The transformation of Luxembourg's industries into the new digital economic paradigm will be assisted by a number of world-class scientific and technical institutions. The Luxembourg Institute of Technology (LIST) was created from the merger of the Gabriel Lippmann and Henri Tudor Public Research Centers. In operation since 1 January 2015, the center was established to provide research and technical support for transitioning Luxembourg's industries into a high-tech digital 21st Century modality. The institute focuses on new materials including nanotechnology, IT services, and environment.

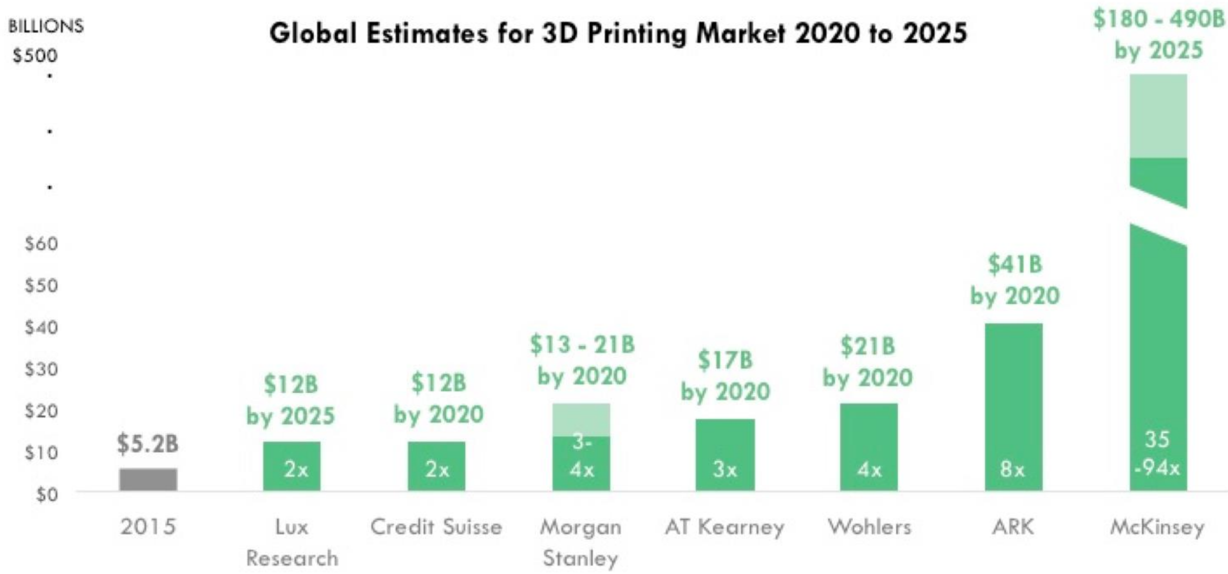
Luxinnovation, the National Agency for Innovation and Research in Luxembourg also plays a prominent role in advancing innovations across Luxembourg's industrial sectors by working directly with enterprises and research organizations. Luxinnovation will help guide the transformation of Luxembourg's industrial sectors into a fully digitalized Third Industrial Revolution economy.

Virtually every industry in Luxembourg will be transformed by the Internet of Things platform and the ushering-in of a Third Industrial Revolution. For example, a new generation of info-facturers in Luxembourg is beginning to plug in to the incipient IoT, and dramatically increasing their productivity while reducing their marginal costs, enabling them to compete in a highly competitive global digital marketplace. It's called 3D printing and it is the manufacturing model that accompanies an IoT economy. Luxembourg hosts a large FabLab called 3DPrint.lu. Engineers, architects, and designers use the technology at 3DPrint.lu to erect urban models, create prototypes for components and products, and repair broken parts.

In 3D printing, software directs molten feedstock inside a printer to build up a physical product layer by layer, creating a fully formed object, even with movable parts, which then pops out of the printer. Like the replicator in the Star Trek television series, the printer can be programmed to produce an infinite variety of products. Printers are already producing products from jewellery and airplane parts to human prostheses, and even parts of cars and buildings.

The early practitioners of 3D printing have made strides to ensure that the software used to program and print physical products remains open source, allowing companies to quickly share new ideas with one another. The elimination of intellectual-property protection also significantly reduces the cost of printing products.

The 3D printing production process is organized completely differently than the manufacturing process of the First and Second Industrial Revolutions. Traditional factory manufacturing is a subtractive process. Raw materials are cut down and winnowed and then assembled to manufacture the final product. In the process, a significant amount of the material is wasted and never finds its way into the end product. Three-dimensional printing, by contrast, is additive info-facturing. The software is directing the molten material to add layer upon layer, creating the product as a whole piece. Additive info-facturing uses one-tenth of the material of subtractive manufacturing, giving the 3D printer a dramatic leg up in efficiency and productivity. 3D printing is projected to grow at a blistering compound annual rate of 106% between now and 2018.[172]



Source: ARK Investment Management LLC (2016)[173]

Innovation Leadership in Green & Circular Additive Manufacturing & 3D Printing

The $5+ billion market in industrial-scale additive manufacturing (AM) and consumer-scale 3D printing reveals the significant potential value to be gained in a wide number of manufacturing venues. Ultra-light materials are being fabricated in the aerospace industry for achieving dramatic fuel savings from light-weighting everything from passenger seats to the skins of aircraft bodies and wings. Freeform curves, lattice structures and intricate shapes that do not follow predictable geometries, are being 3D printed in ways unavailable in traditional manufacturing processes. Similarly, substantial savings are being achieved from integrated designs capable of collapsing scores of parts and components into one continuous 3D printing output, in fields as diverse as automotive bodies to medical devices. These are the kinds of innovations driving AM and 3D printing growth. However, amongst the range of materials

[172] See: http://www.forbes.com/sites/louiscolumbus/2014/12/18/gartner-forecasts-the-3d-printer-market-will-be-13-4b-by-2018/#14a474992552

[173] ARK Investment Management LLC (2016) 3D Printing Market: Analysts Are Underestimating the Future, by Tasha Keeney, April 20, 2016, https://ark-invest.com/research/3d-printing-market.

available – ceramic, metal, and diverse polymers – and the various processes used – jetting or laser, liquid or powder or liquid – not all are green or highly efficient.[174,175,176,177] In fact, the melting required of some polymers are more energy-intensive by one to two orders of magnitude more than conventional industrial practices, while some powders are not recyclable.[178] Moreover, the release of air emissions and fine particles during some 3D printing processes raises health concerns that need to be resolved.[179] In some scenarios, mass scaling of such products would not be sustainable, resulting in excess consumption of resources. Herein lies a great opportunity for Luxembourg's rich array of industrial and manufacturing firms to work closely with the nation's and EU's leading R&D and Innovation centers to further the state-of-play in green, lean, clean, sustainable AM and 3D printing products that fully integrate into a circular economy.

A local 3D printer can also power his or her fabrication lab with green electricity harvested from renewable energy onsite or generated by local producer cooperatives at near zero marginal cost. Small- and medium-sized enterprises in Europe and elsewhere are already beginning to collaborate in regional green-electricity cooperatives to take advantage of lateral scaling.

While 3D printing technology is the digital heart of the new info-facturing processes that are transforming industrial production, a range of other digital technologies coming online also amplify the optimization of aggregate efficiencies and productivity. Virtual product design dramatically shortens the research, development, and deployment of new product lines and reduces the upfront cost of getting the product to market. Smarter robots that can learn from their mistakes and integrate Big Data feedback from other best practices in real time, transforms robotics from a dumb linear mechanical process to a smart cognitive exponential learning curve. Smart robots continually upgrade their capacities by mining incoming Big Data

[174] Faludi, Jeremy, Zhongyin Hu, Shahd Alrashed, Christopher Braunholz, Suneesh Kaul, and Leulekal Kassa (2015) Does Material Choice Drive Sustainability of 3D Printing? World, Academy of Science, Engineering and Technology, *International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering*, v9:2, 2015.

[175] Faludi, J., C. Bayley, M. Iribane, S. Bhogal, (2015) "Comparing Environmental Impacts of Additive Manufacturing vs. Traditional Machining via Life-Cycle Assessment," Journal of Rapid Prototyping.to be published 2015.

[176] Faludi, J., R. Ganeriwala, B. Kelly, T. Rygg, T. Yang, (2014) "Sustainability of 3D Printing vs. Machining: Do Machine Type & Size Matter?" Proceedings of EcoBalance Conference, Japan 2014.

[177] Tabone, Michaelangelo D., James J. Cregg, Eric J. Beckman, and Amy E. Landis (2010) "Sustainability metrics: life cycle assessment and green design in polymers," *Environmental Science & Technology* 44.21.

[178] Oxman, N., J. Laucks, M. Kayser, E. Tsai, and M. Firstenberg Freeform 3D Printing: Towards a Sustainable Approach to Additive Manufacturing, *Mediated Matter Group, MIT Media Lab*.

[179] Stephens, Brent, Parham Azimi, Zeineb El Orch, and Tiffanie Ramos (2013) "Ultrafine particle emissions from desktop 3D printers," *Atmospheric Environment* 79: 334-339.

with analytics. Augmented reality – or virtual reality – allows work teams to be on-site and participate in a work environment as if they were there, allowing them to interact with machines and colleagues in real-time. Eliminating temporal and spatial constraints and boundaries allow global work teams to interact intimately with one another, increasing the efficacy of engagement.

It needs to be emphasized that the smart new info-facturing is only made possible by plugging into the Internet of Things infrastructure. The convergence of the Communication Internet, the digitalized Renewable Energy Internet, and the digitalized automated Transportation and Logistics Internet atop the IoT platform allows info-facturers to dramatically ***increase their productivity and reduce their marginal cost of managing, powering, and moving economic activity across their value chains****. 3D printing, virtual design, robots that learn on the job, and augmented reality work environments will benefit all of the key industrial sectors of Luxembourg in the digital era.*

Many of Europe's global manufacturing enterprises will continue to flourish, but will be fundamentally transformed by the democratization of manufacturing, which favors a high-tech renaissance for small and medium sized enterprises. Europe's manufacturing giants will increasingly partner with a new generation of 3D-printing small and medium sized enterprises in collaborative networks. While much of the manufacturing will be done by SME's that can leverage the increased efficiencies and productivity gains of lateral economies of scale, the giant enterprises will increasingly find value in aggregating, integrating, and managing the marketing and distributing of products.

The transition from the Second to the Third Industrial Revolution will not occur overnight but, rather, take place of over the next 25 to 35 years. Many of today's global corporations will successfully manage the transition by adopting the new distributed and collaborative business models of the Third Industrial Revolution while continuing their traditional Second Industrial Revolution business practices.

The establishment of the Third Industrial Revolution Internet of Things infrastructure in Luxembourg will necessitate the active engagement of virtually every commercial sector, spur commercial innovations, promote Small and Medium Sized Enterprises (SME's), and employ thousands of workers over the next thirty-five years. The power and electricity transmission companies, the telecommunication industry, the construction and real estate industries, the ICT sector, the electronics industry, transportation and logistics, the manufacturing sector, the life-sciences industry, and retail trade will all need to be brought into the process. Many of today's leading companies, as well as new commercial players, will help establish and manage the Internet of Things platform, allowing thousands of others—small, medium, and large sized businesses, nonprofit enterprises, and prosumers—to produce and use renewable energy, automated transportation and logistics, and a panoply of other goods and services at low marginal cost in the exchange economy or at near zero marginal cost in the Sharing Economy.

The Luxembourg communication network will have to be upgraded with the inclusion of universal broadband and free Wi-Fi. The energy infrastructure will need to be transformed from fossil fuel and nuclear power to renewable energies. Thousands of buildings will need to be retrofitted and equipped with renewable energy harvesting installations, and converted into micro power plants. Hydrogen and other storage technologies will have to be built into every layer of the infrastructure to secure intermittent renewable energy. The electricity grid of Luxembourg will have to be transformed into a smart digital Energy Internet to accommodate the flow of energy produced by thousands of green micro power plants. The transportation and logistics sector will have to be digitalized and transformed into an automated GPS-guided driverless network running on smart roads and rail systems. The introduction of electric and fuel cell transportation will require thousands of charging stations. Smart roads, equipped with millions of sensors, feeding real-time information on traffic flows and the movement of freight will also have to be installed.

Semi-skilled, skilled, professional, and knowledge workers will need to be employed across Luxembourg to construct and service the three Internets that make up the digital platform of a Third Industrial Revolution economy. Transforming Luxembourg's energy regime from fossil fuels and nuclear power to renewable energies is extremely labor intensive and will require thousands of workers and spawn new businesses. Retrofitting and converting thousands of existing buildings into green micro-power plants and erecting thousands of new positive micro-power buildings will likewise require thousands of workers and open up new entrepreneurial opportunities for Energy Service Companies (ESCOs), smart-construction companies, and green-appliance producers. Installing hydrogen and other storage technologies across the entire economic infrastructure to manage the flow of green electricity will generate comparable mass employment and new businesses as well.

The reconfiguration of the Luxembourg electricity grid into a Renewable Energy Internet will generate thousands of installation jobs and give birth to cleantech app start-up companies. And finally, rebooting the transport sector from the internal- combustion engine to electric and fuel-cell vehicles will necessitate the makeover of Luxembourg's road system and fueling infrastructure. Installing charging stations along roads and on industrial, commercial, and residential spaces are labor-intensive employment that will require a sizable workforce. The massive build-out of the IoT infrastructure for a Third Industrial Revolution across Luxembourg is going to spur an extended surge of mass wage and salaried labor that will run for forty years or more, spanning two generations.

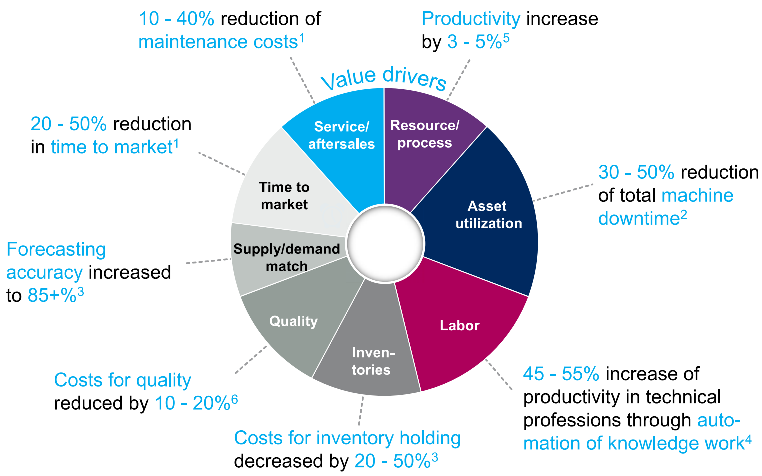
Improvements in aggregate efficiency and productivity across all of the sectors that make up the Luxembourg economy will have a significant impact on new employment opportunities. Based on 2013 data from STATEC, energy services supported 4 jobs per million euro of value-added, compared to 5 in information and communication services, 14 in manufacturing, and 18 in construction and 10 on average throughout the economy (STATEC). Hence, for every one million euro of value-added services generated through greater cost-effect energy efficiency improvements, Luxembourg will gain a net increase of 6 new jobs (that is, instead of supporting 4 jobs, the economy will be supporting an average of 10 jobs, or a net gain of 6 jobs). A 5 billion euro gain in GDP from higher productivity in the Luxembourg economy will lead to higher employment of about 50,000 jobs (all else being equal).

It is important to note the key role that ICT will play in transitioning all of the other commercial and industrial sectors into a digitalized Internet of Things economy. By establishing the critical digital infrastructure to manage, power, and move economic activity across the value chains, ICT becomes an enabler of new job creation throughout the Luxembourg economy.

The business at hand for Luxembourg will be to provide retraining for the existing workforce and the appropriate skill development for students coming into the labor market to ease the transition into the new job categories and business opportunities that come with a massive build-out of an Internet of Things infrastructure.

In summary, the scale up of a smart digitalized Internet of Things infrastructure across Luxembourg will generate new business opportunities, dramatically increase productivity, employ thousands of people, and create an ecologically oriented post-carbon society. The employment of thousands of workers will also stimulate purchasing power and generate new business opportunities and additional employment to serve increased consumer demand. Infrastructure investment always creates a multiplier effect that reverberates across the economy as a whole.

Indicative quantification of digitalization value drivers



Source : McKinsey (2015)[180]

STATE OF PLAY AND LUXEMBOURG VISION

Luxembourg has a strong industrial history which is continuously evolving. Over time, the Grand Duchy of Luxembourg managed to set up a healthy mix of large and medium sized industrial players by relying on a set of advantages including the central location of the country in Europe, its socio-political stability, and its rich pool of qualified workers. These assets played an important key role in attracting foreign direct investment and helped establish the activities of several world-class industrial actors. A substantial number of multinationals such as Arcelor Mittal, Goodyear, Dupont de Nemours, Husky, Guardian, and Delphi are currently pursuing their activities on the Luxembourg territory. These companies represent a strong foundation for the future development of Luxembourg industry. Additionally, a number of "Hidden champions" is active in Luxembourg including IEE, Accumalux, Rotarex, Ceratizit, ELTH, and Paul Wurth. Most of them companies produce lesser-known products, but in the markets they produce for, they are ranked among the top ten in the world.

[180] McKinsey (2015) Industry 4.0 How to navigate digitization of the manufacturing sector. According to McKinsey, "[I]nformation itself does not have an inherent value. All data collection should be approached with the objective of maximizing value. We thus need to look out for concrete value drivers across the business (i.e., areas where inefficiencies occur due to information leakages). For example, machinery and assets are a significant cost category for manufacturing companies; therefore, asset utilization is a value driver that might contain untapped potential due to information leakages." (p. 22)

Despite its small size, the country has a diverse number of industrial sectors. The steel industry enjoys a long tradition in Luxembourg and is still one of the main players in the country's economy. In addition to the steel industry, Luxembourg boasts several other related industries including the processing of metals and the manufacturing of metal articles. The chemical industry is another important sector, with its main activities evolving around processing chemical products. Luxembourg also hosts companies involved in the production of non-metallic mineral products, glass, lumber, and raw materials used in the construction sector. The food industry and the manufacturing of beverages and tobacco are also important historic players in Luxembourg.

Employment in industry remained quite stable over the last 20 years in Luxembourg (1960: 35,000 vs. 2015: 36,600).[181] Interestingly, several structural changes occurred within the Luxembourg industry. The steel industry, which heavily dominated the economy in the 1970s, scaled back over the last several decades (1974: 25,000; 1985: 13,000; 2010: 6,000).[182] Meanwhile, the other manufacturing industries gained in market share (1960: 11,200; 2010: 23,900). In comparison to its neighboring countries, Luxembourg performed quite well. In Belgium, for example, industrial employment declined during the same period by 50%, in France by 36% and in Germany by 22%. In Italy and the Netherlands, industrial employment remained stable.

The manufacturing industry made up 44% of the value added generated in the entire economy in 1970. Today, the contribution of manufacturing has fallen to approximately 5%. This heavy loss in "relative terms" is closely linked to the staggering growth of the services sector during the 80s, 90s and 2000s. However, the stagnation and the decline of certain industrial activities also contributed to this evolution, especially in the aftermath of the Great Recession.

Remaining competitive on the international level is one of the key challenges faced by Luxembourg's industrial sectors. Not surprisingly, given the small size of the Luxembourg economy, international trade constitutes the main driver of Luxembourg's economic development. Luxembourg's industrial sector exports about 85% of its production and, in some sectors, exports account for nearly 90% of production. Luxembourg's main trading partners are its neighboring countries: 28% of the production is exported towards Germany, 15% to France, and 12% to Belgium. On the whole, 81% of the exported goods are flowing into an EU country, 5.2% to the Americas and 5.6% to Asia (2012).

The very notion of what constitutes an industry is evolving with the introduction of a digitalized Third Industrial Revolution paradigm. As the Industry Working Group has pointed out, the shift

[181] Source: Les autres industries manufacturière. STATEC
[182] Source : L'industrie sidérurgique depuis les années 60. STATEC

to a digital infrastructure brings with it new business models and business practices that converge products and services in an economy that is moving from conventional ownership in markets to nontraditional access to services and networks. The Working Group emphasizes the fact that the shift to a digital infrastructure will bring with it not only new business practices, but also significant challenges including the country's lack of qualified engineers and other technical personnel.

With this in mind, the Industry Working Group has adopted a set of guiding principles that will take the Grand Duchy of Luxembourg into an Internet of Things Third Industrial Revolution economy. The guiding principles are the set of values that will guide Luxembourg Industry in all circumstances, irrespective of changes in its goals, strategies, type of work, or governance. By pursuing the path based on values and holding one another accountable to the sector's standards, the values become the fabric of the industrial culture. Those guiding principles are also essential in order to encourage the right behavior while advancing the transition into the Third Industrial Revolution. The values are derived from the history and culture of Luxembourg and are linked to the size of the country and existing interactions with neighboring countries.

Multi-lingualism: Luxembourg's strength is a versatility of spoken languages on a daily basis, three of which (Luxembourgish, French, and German) are official national languages, with English and Portuguese spoken by many people.

Open-mindedness: receptively and actively chasing new ideas, new concepts and new industries; adopt an open approach towards the views and knowledge of others.

Collaboration: the process of working together to the same end (e.g. public-private partnerships).

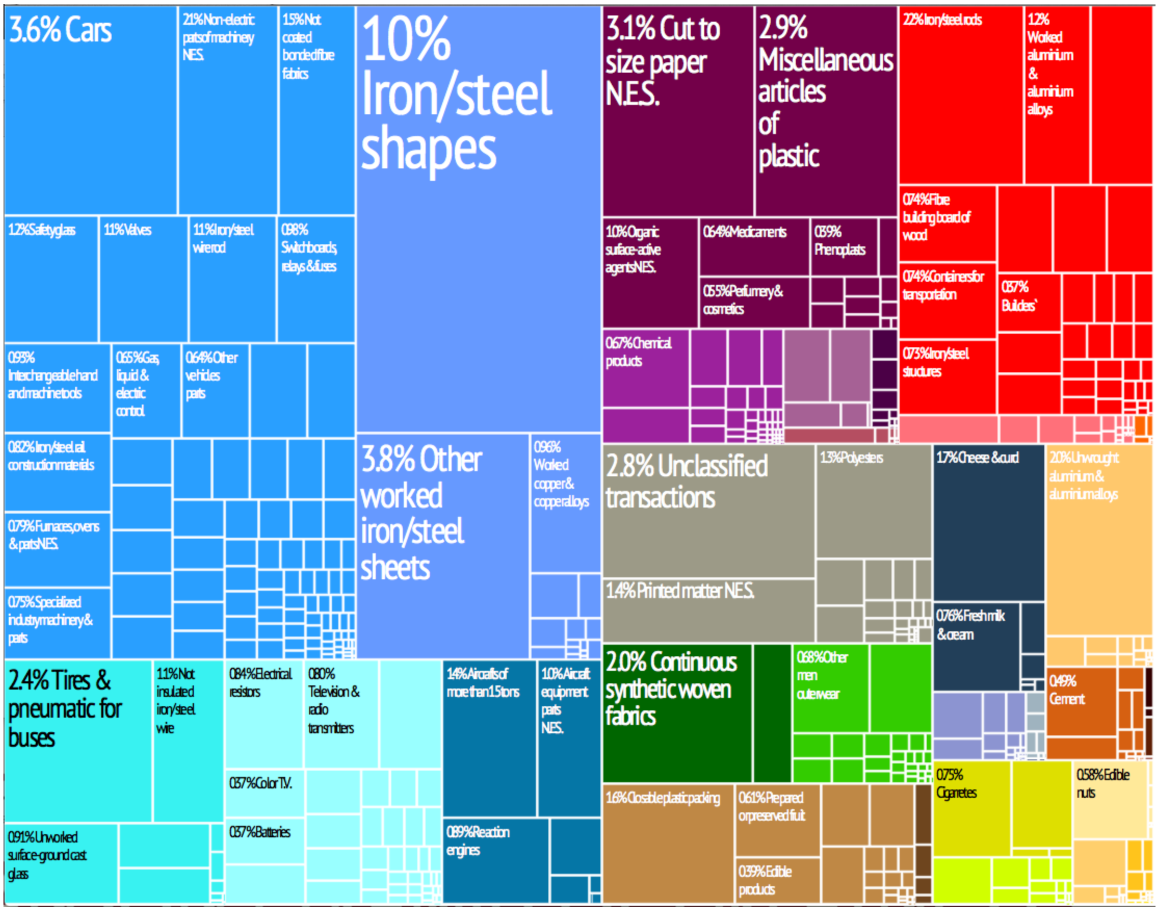
Drive and embrace change: change is the only constant. We must learn not to fear change, but to embrace it and even encourage and drive it and have the courage to give up what cannot be sustained. Companies come and go, and have to be resilient and embrace continuous improvement.

Pursue growth and learning: reflect on the areas where you excel or have an interest and try to learn more about those areas but also means to reflect on areas where you can further improve.

Do more with less: eliminate/reduce "waste." Lean principles – save on resources, time, money and energy.

Luxembourg Industry Vision

As the Industry Working Group emphasizes, Luxembourg industry exports about 85% of its production, exceeding 90% for some sectors. The accompanying graph from the MIT Atlas of Economic Complexity highlights these product exports.



Graphical depiction of Luxembourg's product exports in 28 color-coded categories. Source: Haussmann, Robert, Cesar Hidalgo *et al* (2014) The Atlas of Economic Complexity, Mapping Paths to Prosperity, Electronic Complexity Observatory, MIT Media Lab and the Center for International Development.

A multitude of factors are continuously challenging the competitiveness of these products and firms: global market turbulence, technology disruptions, intra-industry rivalry, extra-industry forces, regulatory requirements in production processes and product attributes, taxation changes, fluctuations in factor input cost and availability, alterations in risk insurance, etc.

Digital Single Europe & Digitizing European Industry

The European Commission is moving forward with the establishment of the European cloud in tandem with the Digital Single Europe initiative. Among its numerous functions will be connecting Europe's 70 million science, technology and engineering professionals and 1.7 million researchers to a vast repository of research data. This open source virtual storage and retrieval network will enable professionals and researchers to access and share voluminous amounts of data and information for performing analyses and applying to new uses and innovative applications. The European Commission estimates more than €50 billion of public and private funds will go into digitization of industry.[183] It has been estimated that EU industry revenue will increase by an additional €110 billion per annum over the next 60 months as a result of this digitization of industry.[184]

New Business Models for TIR

The myriad of challenges puts a premium on Business Model Innovation (BMI) initiatives, a point succinctly summed up by the Working Group, *"The past has shown that 'waves' of disruption are regularly challenging our companies in Luxembourg. Some companies will disappear; new ones will emerge. Hence it is important as well to detect the opportunities of tomorrow and help promising entities to seize their chance to become a leading actor of tomorrow's industry."*

As such, a bold vision statement sums up what the Luxembourg industry hopes to accomplish:

"Luxembourg: an internationally recognized platform for sustainable Industrial excellence through innovative solutions"

The Working Group on Industry created a common vision for industries established in Luxembourg. The vision should provide both the guidance and inspiration necessary throughout this transformational process. It is a brief, but powerful statement, one that is aimed at helping all stakeholders in their efforts to address the challenges and opportunities of the Third Industrial Revolution.

[183] EC (2016) **Commission sets out path to Digitise European industry, European Commission,** April 19, 2016, http://europa.eu/rapid/press-release_IP-16-1407_en.htm.

[184] EC (2016) Digital Single Market – Digitising European Industry Questions & Answers, European Commission, April 19, 2016, http://europa.eu/rapid/press-release_IP-16-1407_en.htm.

The first part of the sentence "An internationally recognized platform for sustainable industrial excellence" represents the goal the Luxembourg industry would like to achieve, while the second part of the sentence "innovative solutions" are the means required to reach this goal. It is important to stress here, that the vision is a unique statement only applicable in the context of the Luxembourgish environment.

Glossary:

Internationally recognized Platform: a vibrant cluster of stakeholders who have a strong vested interest in the development of Industries. These stakeholders come from both the public and private sector. The concept of the Public Private Partnership is the cornerstone of the whole initiative.

Sustainable: mindful use of resources (energy and raw materials), investment in people (safe and skill-enhancing working conditions) and profitable. The principles of the circular economy are fully acknowledged and recognized.

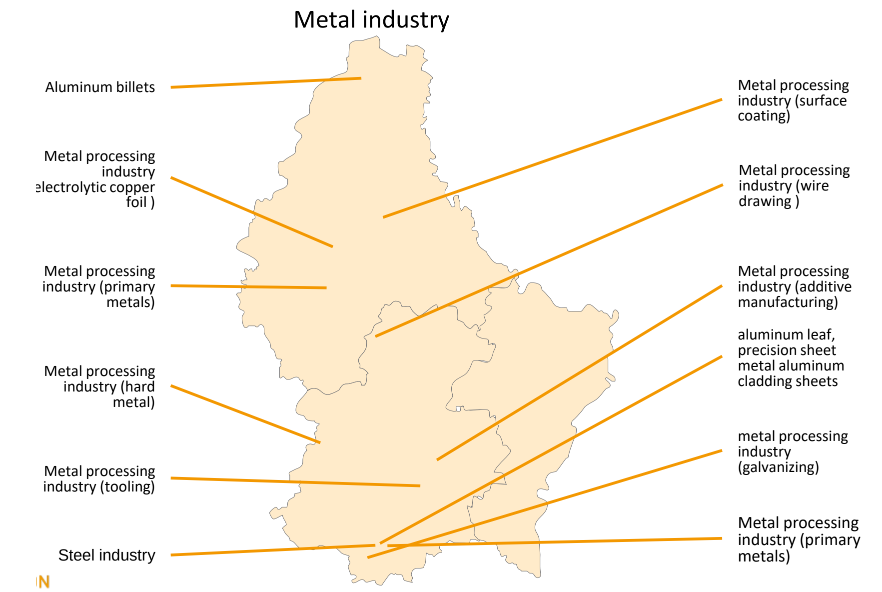
Industrial Excellence: production of world-renowned and high quality industrial products. The Business Model for these products may be a standard purchase model of a product, or the delivery of this product as a service.

Innovative: exploit the symbiotic link between research and industries. The focus is on applied research.

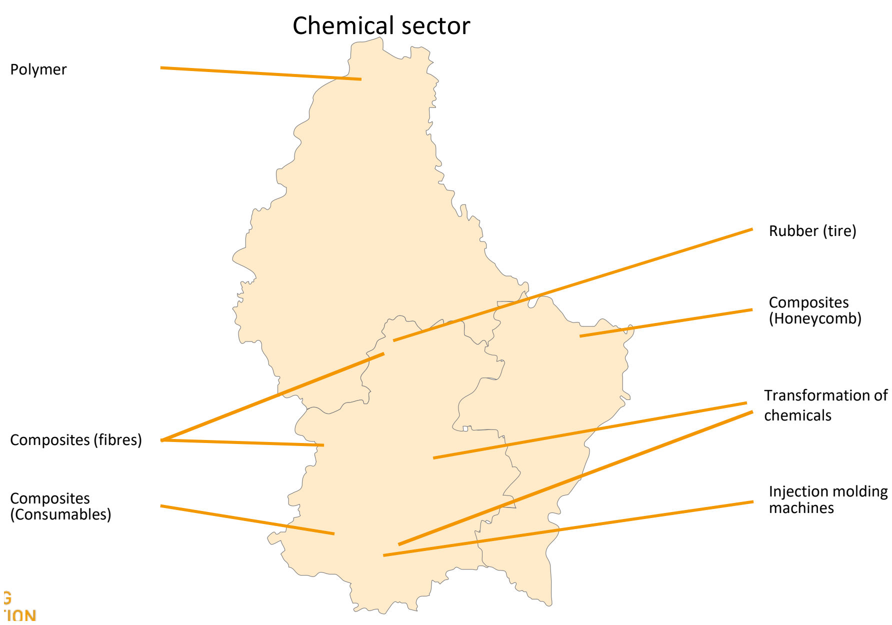
Solutions: offering solutions (products, services, hybrid models) to end-customers.

While the vision statement describes what Luxembourg Industry wants to be in the future, the Working Group also proposes a mission statement. The mission statement should guide the actions and strategies, and provide a path and guide the decision making process.

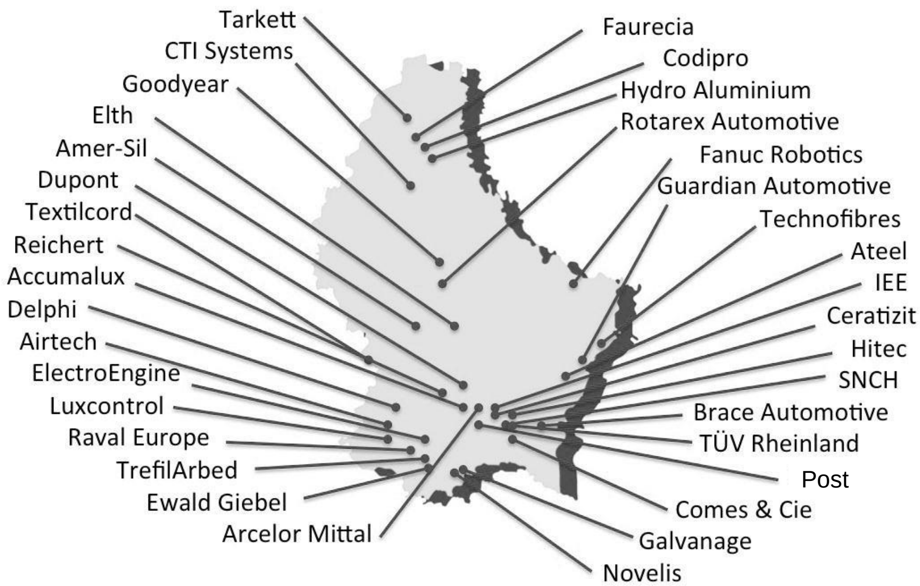
"Develop an ecosystem that will be a fertile ground for the development of industrial products and services which will be innovative, mindful of any environmental impact, thrifty in its use of the Earth's limited resources and enabling the transformation of the economy from a carbon fossil model to renewable energy."



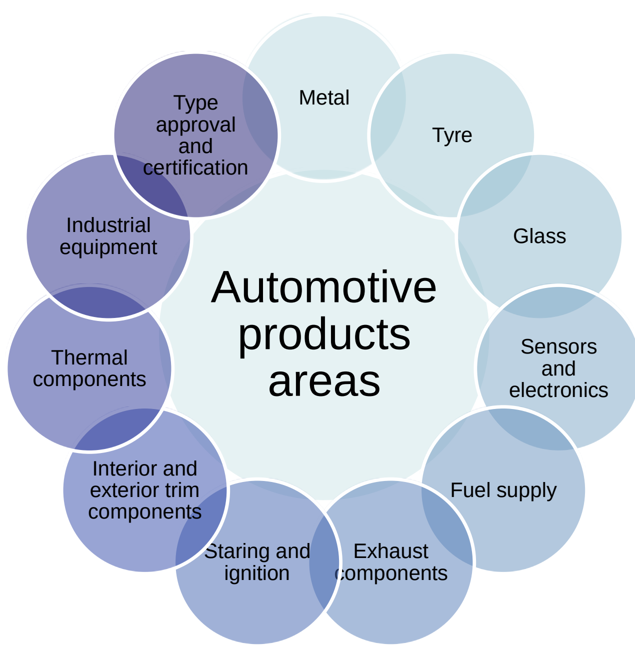
Source: Luxembourg Materials Center Cluster Presentation 2014



Source: Luxembourg Materials Center Cluster Presentation 2014



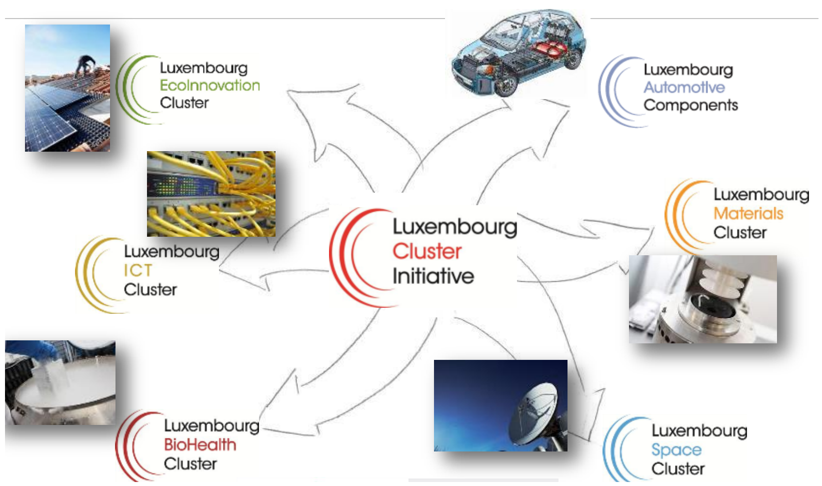
Source: Luxembourg Materials Center Cluster Presentation 2014



Source: Luxembourg Materials Center Cluster Presentation 2014

Accomplishing exergetic efficiency-productivity gains have become economic, business, and environmental imperatives for the entire €70 trillion global economy. Exergetic growth rates need to exceed economic growth rates in order to drive the engine of aggregate efficiencies across value chains, and significantly increase productivity, while dramatically shrinking ecological footprints. Low and slow exergetic improvement rates drag down the economy, jeopardizing business stability, employment, and dampening innovation. Innovation flourishes, trade expands, businesses thrive, and society and the environment benefit with higher and faster exergetic improvement rates.

The Industry Working Group seized this insight by zeroing in on three key topics holding a vast potential for exergetic gains: 1) Energy and Resource Efficiency, 2) Research, Development & Innovation (RDI), and 3) Smart Industry and IoT Integration. The Working group emphasizes, "*These subjects converge at all times and should not be viewed in isolation*."



Energy and Resource Efficiency

Over the next 35 years, total energy use in Luxembourg could be cut by as much as one-half through the greater use of energy efficiency across all economic sectors and households. It is crucial to pinpoint the total energy consumption of industries in this country. Secondly, it will be important to highlight the sources of the energy purchased by industries. What is the percentage of energy that could be qualified as renewable? Here we are talking about energy that is purchased and hence produced by a third party. But the interesting questions go further: Will industries be able to significantly reduce the level of energy they require for production? There are physical limits to energy efficiency that will prevent heavy energy-consuming industries from reducing their level of energy use. Will industries be able to produce significant energy themselves? This could be achieved through different means (solar, wind, geothermal, biomass). Finally, there is the central question of waste. Many production processes produce heat. How could industry turn this thermal energy into reusable energy to be used by a third party? For example, consider Luxembourg's glass industry. This is a high-energy consumption industry. During the production process, water with a temperature of 57 degrees is used to run over the finished product (glass). That water is considered to be waste and will flow into the drain and be recycled. An investment would be necessary to use that thermal energy (in the form of warm water) to potentially heat a communal swimming pool or a building. The same is true for steel production. Recuperation of heat energy from cooling steel beams at Arcelor Mittal's walking beams furnace has significant potential. Clearly both the plant and the consumer would have to be situated in regional proximity to prevent energy losses.

The challenge is straightforward: increase energy efficiency and render energy production more sustainable through wind, solar or other renewable technologies. In this regard, industries should be encouraged to use all available free space on roofs and in parking lots to produce solar energy which they can both use and return to the power grid. The exploration of new ways to encourage the storage of energy should be actively promoted.

As previously mentioned, the smart grid will be a critical component in the paradigm shift to a Third Industrial Revolution. Smart grid technology will give industries real time information on their energy consumption profiles. This will help them better align their sources of energy (buy or produce) and if they buy, the buying pattern could be optimized and result in cost savings. Simply put, energy peaks are expensive.

At the same time, Luxembourg industries will need to explore the potential of reusing waste heat and materials to close the production and consumption cycle. This is an important step to avoid any waste leakages and to maintain the longevity of the input materials. There is also a strong link between the construction and the industrial sector. A number of industries producing building materials such as concrete, glass, and steel are well-established in Luxembourg. At present, the construction sector is required to deliver buildings which have to meet very high standards in regards to energy efficiency. This trend is continuing, and at some point in the future, it may well be that new buildings will have to be built of materials which are 100% recyclable/reusable.

Rethinking Energy Services

Vintage Second Industrial Revolution energy industries are being buffeted by relentless storms brought on by the IoT and GAIN (genetic, auto-robotic, informatics and nano-engineering) technology advancements driving the Third Industrial Revolution. These general-purpose technologies offer the means to deliver energy services more competitively with substantially smaller ecological footprints.

This is pointedly seen in the staggering decline of wind and solar PV power costs, which are sometimes cheaper in the United States than fossil or nuclear power options. Lawrence Berkeley National Lab's annual review of long-term Power Purchase Agreements (PPAs) find the levelized cost of electricity (LCOE) to be 2.5 cents per kWh for wind power and under 4 cents/kWh for utility-scale solar PV plants, located in good sites (and recently under 3 cents/kWh in Dubai). Deutsche Bank predicts solar grid parity in 80% of the global market by 2017.

Competitive price is just one important criteria of the overall value of wind and solar. Equally important is the fact that their risk profile is significantly lower than traditional fossil and nuclear resources, as well as some other renewable resources like large-scale biomass plantations and large hydrodams. Solar PV and wind power are not dependent on transported fuel inputs, require 95% less water than thermal power plants to generate each kWh of electricity, and, during generation, release no emissions, air pollutants, toxic sludge contaminants, or radioactive wastes requiring permanent isolation.

Unlike with nuclear power, wind and solar do not require catastrophic accident insurance. Wind and solar have a small land footprint that is 30 to 60 times smaller, respectively, than biofuel crops. These risk-free attributes are of special concern for the uncertain world of the 21st Century, where cyber-terrorism could trigger Chernobyl and Fukushima type disasters, or worse, whereas solar and wind power systems fail gracefully, not catastrophically, and are capable of quickly rebounding.

Developing an Eco-system Strategy that Encourages, Stimulates, and Increases the Innovative Capacity of Industrial Companies

The development of an eco-system for research and development, with a special focus on applied research, will be one of the key elements that will help to develop "innovative solutions" in order to attain "industrial excellence." The aim is to set up common platforms that facilitate cooperation between the University of Luxembourg, CRPS and private companies. Scientific research shall support national industry to enhance competitiveness. Luxembourg can rely on a strong industrial history with a healthy mix of large sized and small and medium sized companies. Industry in Luxembourg has a strong focus on high value added products and services and benefits from short and flexible decision making. Moreover, there are strong links with other sectors promoted and developed in Luxembourg such as logistics hub and eco-technologies; and strong support vehicles (public funding, Industry oriented public research) are made available by the public institutions with the ambition to create industrial eco systems.

However, several weaknesses have to be taken into account: Decline in private investment in research; limited collaboration culture which is fragmented and individualistic (public and private); weak public opinion of (dirty) industry; missing critical mass in sectoral value chains; absence of seed venture capital for industry; and research is currently too focused on fundamental (theoretical) research instead of applied research, linked to industrial needs.

There are several possibilities ahead. Focusing on multi-company research may benefit more than one company and allows for the sharing of research infrastructure, the joint development of key enabling transversal technologies and profit from joint staff appointments (e.g. development of mathematical models that can be shared with several stakeholders). Research does not necessarily need to be related to product development, but other topics of common concern such as solutions for more energy efficiency or common manufacturing technologies can be the fruit of a common research project that may benefit the industry on the whole. The potential of cross-sectoral cooperation may be quite easy to activate in Luxembourg as most industries are not in direct competition with each other. This common approach is also interesting from a financial point of view as it allows one to use the available resources more efficiently. There is an equally important opportunity to capitalize on public funds offered by Europe.

More Public Private Partnerships will be key. Luxembourg will have to find a common denominator that reflects the diversity of its industry and their scientific and technological needs with those of public research (align public and private research priorities). There is also a need to scale-up investment in technological research excellence to international levels and get the stakeholders to devote their resources to common RDI projects. Here, the question of risk sharing is also crucial.

Common platform to test new viable business models

It should not only be about reinforcing existing industries and companies but about offering a platform to develop new promising start-ups and new business models. The past has shown that “waves” of disruption are regularly challenging companies in Luxembourg. Some companies will disappear while new ones will emerge. It is therefore important to detect the opportunities of tomorrow and help promising entities seize their chance to become a leading actor of tomorrow’s industry.

Smart IoT Integration

Smart Industry is a new stage of organization and control of the entire value chain of the lifecycle of products. This lifecycle will increasingly be determined by individual customer preferences and will extend from the idea, the development and production, the delivery of the product to the end client, the recycling stage, and all relevant services.

All members of the working group agreed that their business environment is increasing in complexity year by year. Having the right product at the right time is becoming more and more complex. Customers are constantly challenging companies and require them to be more and more flexible.

Smart Industry bears the potential to revolutionize supply chains. We are unable to imagine today what the possibilities will be over the coming years. We believe that we are just at the beginning of this process.

The driver for this revolution is the Internet. The Internet has transformed our world in a way that hardly any other technology has done in the past. Information is at our fingertips and accessible anytime from everywhere. This was the foundation for social media.

Web 2.0 made it possible for mankind to be connected in real time in a many-to-many format. Now we will be able to add things or objects to this network. These things will become autonomous actors. We refer to this evolution commonly as the Internet of Things or Internet of Services. It is important to understand that beyond the connection of objects we will be able to add an application layer that will allow computers to recognize and sort the contextual importance of information.

The basis for all of this is the availability of all relevant information in real time through the connection (network) of all instances (machines, people) which are part of the value chain. In addition, the system and the “system of systems” will have the capability to determine the optimum flow of value creation through the analysis of the data.

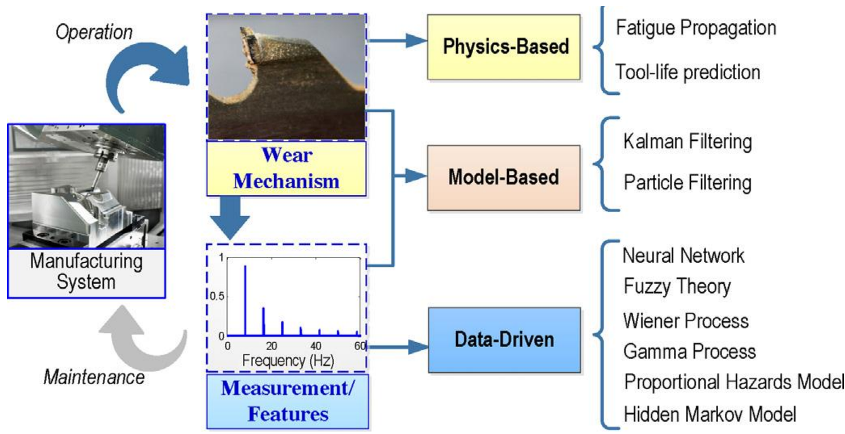
Through the connection of people, objects and systems, dynamic self-organizing cross organizational value chains will emerge. These value chains will be able to optimize in terms of costs, availability and resource consumption. We are moving from a centralized to a distributed form of plant planning and control. We are not referring to new production techniques i.e. additive manufacturing. We are referring to a totally new organizational framework. Innovative production techniques will be integrated into this new framework but they do not represent the point of origin.

IoT-Enabled Prognosis in Industry and Manufacturing

Among the value-added benefits emerging from the Internet of Things (IoT) is the application of system-level prognostic and predictive science throughout the industrial sectors. Cloud, fog, edge and distributed computing,[185,186] reliant upon pervasive wireless smart sensor networks and Big Data analytics and smart algorithms, enables robust operational reliability, enhanced service life, reduced capital and operating expenditures, and accrued productivity gains by performing continuous intelligent preventive maintenance, fault detection and diagnosis, asset management, and rigorous system design.

As recently summed up in *Cloud-enabled prognosis for manufacturing*, "Advanced manufacturing depends on the timely acquisition, distribution, and utilization of information from machines and processes across spatial boundaries. These activities can improve accuracy and reliability in predicting resource needs and allocation, maintenance scheduling, and remaining service life of equipment. As an emerging infrastructure, cloud computing provides new opportunities to achieve the goals of advanced manufacturing."[187]

Classification of Prognosis Methods



Source: Gao et al (2015)[188]

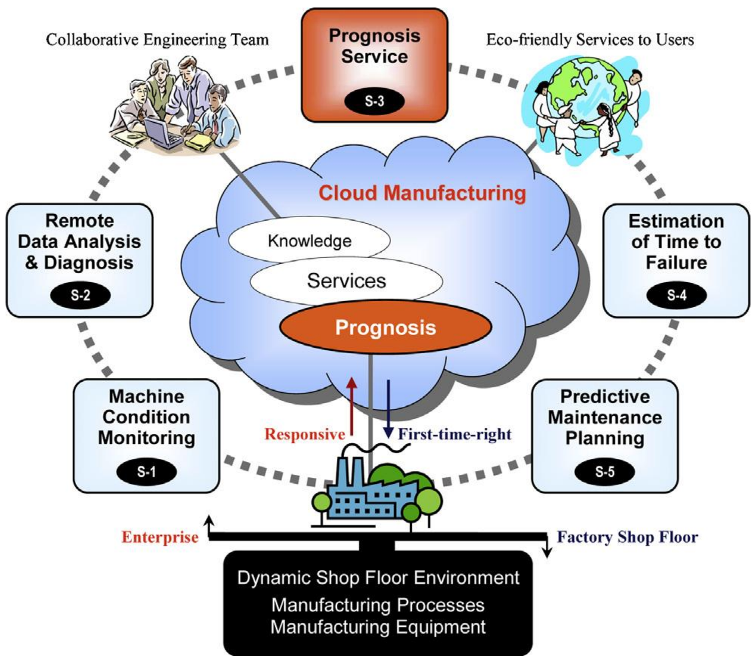
[185] Mitchell, Gary (2015) Open Fog Consortium to Help Enable Scenarios for the Internet of Things, themanufacturingconnection.com, December 2015, http://themanufacturingconnection.com/2015/12/open-fog-consortium-to-help-enable-scenarios-for-the-internet-of-things/.

[186] Enescu, Michael (2014) "From Cloud to Fog & The Internet of Things" LinuxCon, Chicago, http://www.slideshare.net/MichaelEnescu/michael-enescu-keynote-chicago2014fromcloudtofogandiot.

[187] Gao, R., L. Wang, R. Teti *et al*. (2015) Cloud-enabled prognosis for manufacturing, *CIRP Annals - Manufacturing Technology*, http://dx.doi.org/10.1016/j.cirp.2015.05.011

[188] *Ibid*., Gao *et al*. (2015)

Architecture of cloud-enabled prognosis



Source: Gao et al (2015)[189]

Transversal Topics

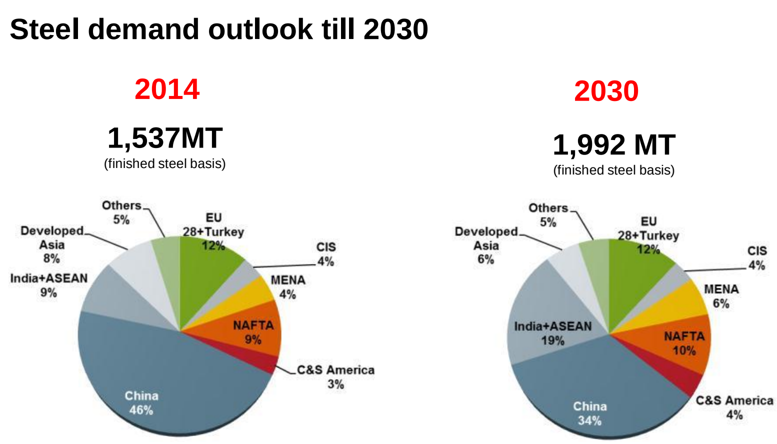
The legal and regulatory framework will be an important tool to accompany the evolutions in "Energy & Resource efficiency," "Research, Development & Innovation" and "Smart Industry." Binding legislation, fiscal incentives, and a definition of best practices in the use of resources and/or changes in the 'culture' of entrepreneurs (an environment where someone is motivated to innovate, create and take risks by taking long-term sustainability issues into account) are essential subject matters for putting Luxembourg on the road toward the Third Industrial Revolution. It is important to stress that, as a sovereign state, Luxembourg has the authority of a governing body to implement, to a certain extent, the right legislative and regulatory tools that may encourage a transparent and simple possible authorization process for industrial activities and change in activity that are in line with the principles of the Third Industrial Revolution. Moreover, the question of the availability of the right skill set is crucial for the development of the industry in the context of the Third Industrial Revolution. Attracting, retaining and training of high-qualified workers will be key for a sustainable development across all of Luxembourg industry. However, the whereabouts of less qualified personnel

[189] *Ibid*., Gao *et al*. (2015)

should not be neglected in the transition phase and should retain the attention of the stakeholders as well.

Steel Industry

What does solar and wind technology portend for sustaining and expanding the export potential of Luxembourg's industrial sector? The steel industry, for example, continues to face considerable market volatility for a number of reasons. Growth is slowing, with the following chart showing the World Steel Association's projection to 2030.



Source: World Steel Association, Global Steel Market Outlook
OECD Steel Committee Meeting Paris, 11-12 May 2015

Despite the lower growth rates, the market is particularly favorable for specialty products and high-grade steels. ArcelorMittal's $80 billion in sales shipping 85 million tonnes of value-added steel product in 2014 would appear to be well-positioned for capturing a robust share of the 1.9 billion tonnes global steel market in 2030, despite ongoing displacement of steel products in the materials market.

For example, steel confronts new competition from advanced ultra-light materials such as the rising application of carbon composites in the vehicle industry. In addition, the Internet of Things, Services, and Networks (IoT, IoS, IoN) are enabling radical makeovers not only in products, but also in the very nature of how a service such as mobility is delivered. With the scale-up of car-sharing operations, augmented by the emergence of autonomous/ driverless vehicles, there is likely to be a decline in private car ownership, with a consequent drop in vehicle manufacturing levels and the demand for steel. Carbon composites and lighter weight aluminium further diminish the percentage of steel used in cars, although specialized, high-value steel materials will continue to compete for key components of vehicles.

For example, ArcelorMittal is the world's leading steel supplier to the automotive industry, and the steel giant is immersed in promoting sustainable mobility over the past decade as part of the Future Steel Vehicle (FSV) initiative. The FSV consortium focused on cleansheet designs for the expanding electric vehicle market. ArcelorMittal has made tremendous strides in light-weighting the EV underbody's total weight by 20% using advanced high-strength steels and ultra high-strength steels (Usibor® and Ductibor®). These steel products now constitute over 85% of the underbody.

ArcelorMittal also uses its advanced steels in intelligent design of vehicle components for deriving multiple benefits like increased safety, reduced emissions, and reduced metal waste, in addition to reducing emissions and fuel consumption during vehicle use. Co-engineering with automakers, ArcelorMittal generates optimized steel specifications with innovative tools like laser-welded blanks to get the right steel in the right place.

In the energy sector, the steel consumed in the coal, oil and gas industries is on a declining path, given the urgency of eliminating emissions and pollution. The steel market for nuclear reactors is also declining, given the recognition that living with reactors means living with the intrinsic risk of a fat-tail probability of catastrophic disaster, whether triggered by nature, technical failure, human error, or malicious terrorist attack.

Chemical Composites

Shifting markets to composites and other material substitutions means new business opportunities for non-steel industrial and manufacturing sub-sectors. Luxembourg-based corporation DuPont has been co-engineering lighter weight components with automakers, using a range of high-performance polymers to displace metals. For example, DuPont developed innovative nylon resin products (Minlon® and Zytel® PLUS) that are instrumental in fabricating engine components capable of withstanding harsh chemicals, scorching temperatures, and extreme pressures. Other DuPont™ products, like the thermoplastic Delrin® has been valuable for engineering levers and gears and other functional components.

But shifting to solar and wind technologies offer multi-trillion euro new business opportunities for both the steel industry and other manufacturers.

Advanced Steel and Composites

According to the World Steel Association, steel comprises four-fifths of the materials used to construct and install wind turbines, and 90% of that steel is recyclable at the end of the wind turbine's lifespan, resulting in significant reductions in CO_2 emissions compared to primary steel production.

OFFshore Wind

Two examples help illuminate the potential market for steel in the offshore wind market. In 2002, the installation of 160 MW of offshore wind turbines at Horns Rev (Horns Reef) 15 kilometers off the coast of Denmark required 28,000 tonnes of steel. That is roughly 175 tonnes of steel per MW. By 2016, ArcelorMittal participated with Statoil and Siemens in the offshore 30 MW Hywind Park situated 25 km off the coast of Scotland. The six 5 MW turbines required 3,500 tonnes of steel, or 116 tons of steel per MW.

The 2015 global 100% renewables energy assessment conducted by a joint team of Stanford University and UC Berkeley scientists, engineers and economic analysts calculated the global wind market opportunity over the next 35 years.[190] They assumed wind turbines located in roughly one-quarter (~27%) of the near-shore offshore wind technical resource potential. This amounts to 760,000 wind turbines (5 MW each), which would satisfy ~13% of total global energy consumption. The 3.8 million MW of installed offshore wind capacity represents an €11.7 trillion (2013€) global market opportunity. Assuming 100 tonnes of steel per offshore MW, suggests a global market opportunity of 380 million tonnes of steel worth a quarter trillion euros (2016€).

There is also a circular economy crossover benefit of working with the concrete and cement industry in creating steel-in-concrete and steel-around-concrete foundations. As the World Steel Association spells out, "To improve durability and achieve longer-term strength, 70% of the cement in a concrete foundation can be replaced with ground granulated blast furnace slag (GGBS), a by-product from the steel industry. In many cement or concrete applications, this is the most cost-effective method for strengthening foundations because it adds no overall cost. Furthermore, compared to a foundation that does not use GGBS, it saves an average of 92 tonnes of CO_2 per foundation manufactured."[191]

The circular economy is also facilitated by the reuse of 90% of the steel in wind turbines at the end of their 20 to 30 year lifespans, shrinking the ecological footprints involved in extractive mining, the amount of energy and water required in virgin processing, and levels of CO_2 emissions, air pollutants, and wastes.

[190] Jacobson, Mark and Mark Delucchi et al. (2015) 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All- Sector Energy Roadmaps for 139 Countries of the World, December 2015, https://web.stanford.edu/group/efmh/jacobson/Articles/I/susenergy2030.html.

[191] WSA (2012) Steel Solutions in the Green Economy, Wind Turbines, World Steel Association.

ONshore Wind

Onshore wind power offers an equally enormous, attractive global market opportunity for the steel industry, as well as for other manufacturing, financial, insurance, and IoS-based wind (virtual, remote) operations and maintenance sectors.

The 2015 global 100% renewables energy assessment proposes relying on just 3.5% of the onshore technical potential for locating turbines by 2050. This amounts to roughly 1.2 million onshore wind turbines (5 MW each). The 6.35 million MWs of installed capacity represent a global market opportunity of €7.2 trillion (2013€), providing 20% of total global energy needs within the next 35 years. This amounts to a global potential market of 635 million tonnes of steel, assuming 100 tonnes of steel per MW, at a worth of a quarter trillion euros (2016€).

Solar Power

Solar PV and CSP installations, with the need for steel posts, merchant bars, and beams also represent an immense global market opportunity for the steel industry. The 2015 global 100% renewable energy assessment estimates 25 million MWs of utility-scale solar PV power plants, seven million MW of rooftop solar PV systems, and 1.5 million MW of concentrated solar power (CSP) plants that collectively could generate 60% of total global energy needs by 2050. The global market opportunity exceeds €65 trillion (2013€). The solar power systems would occupy less than one-third of 1 percent of land area, averaged worldwide.

As the global assessment indicates, solar and wind can provide 90% of total global energy requirements, including power for the electrification of the transport sector and many other energy services that currently rely on fossil fuels. The greater efficiency of electrification over thermal combustion results in an overall global energy efficiency boost of 40%. Remaining parts of the economy incapable of electrification could be satisfied with conversion of excess solar and wind into hydrogen fuels, and a modest amount of biofuels where less expensive than hydrogen fuel use.

The steel industry will also be instrumental in the electrification markets for transmission and distribution power lines, in the pipelines necessary for transporting hydrogen fuels, as well as in mining operations for the numerous resources that go into the wind and solar technologies.

This detailed, transparent assessment is illustrative of the economic opportunity of substantially reducing fossil fuels and nuclear resources by 2050. The actual percentages of wind versus solar will vary within nations, regions, and worldwide, which, beyond geographical differences, is partly driven by the competition between the differential learning and experience curves that continue to drive down costs and increase performance of each technology.

The assessment is not a prediction, since there are countervailing forces overtly attempting to block displacement of fossil fuels and nuclear resource development, and there are unwitting barriers that should be superseded, notably updating public utility planning and approval regulations, removing subversive tax subsidies, and accounting for the fully monetized costs of non-regulated externalities so as to effectively phase out the competitive advantage of fossil fuels over solar and wind. According to the 2015 assessment by the International Monetary Fund (IMF), worldwide subsidies to the fossil fuel industry exceed €5 trillion per year.

On the upside, as transparently detailed in the Stanford/UC Berkeley assessment, the economic and social benefits are immense, summarized in the following box. The energy transformation will save the average person worldwide $30/year in fuel costs, ~$370/year in health costs, and $1,820/year in climate costs (2013 dollars).

TIR GLOBAL ENERGY MARKET OPPORTUNITIES

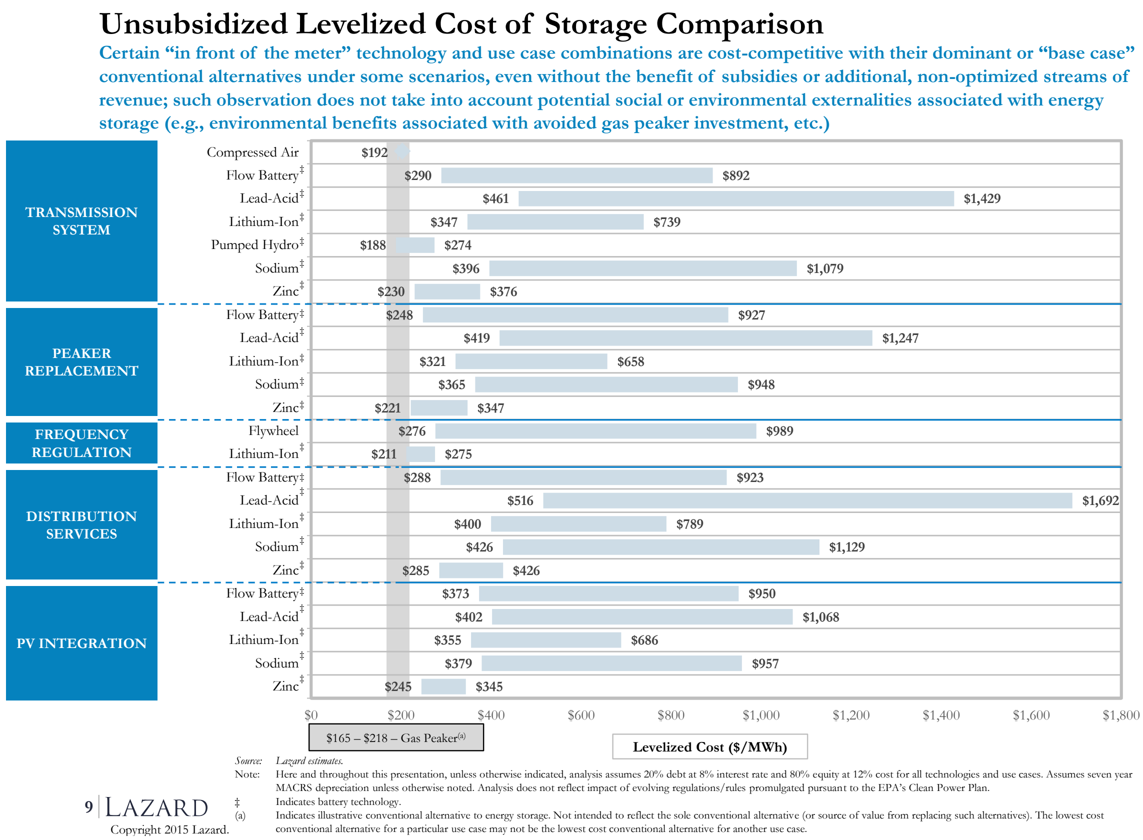
Renewable powered electrical conversion of 139 nations projected by 2050 to:

◆ Create 23 million 35-year construction jobs and 17.5 million 35-year operation jobs for the energy facilities alone, the total outweighing by ~3 million the 37 million fossil & nuclear jobs lost.

◆Avert ~4.6 million premature air pollution mortalities per year in the 139 countries and avoid ~€2.9 trillion/year in health costs (2015 dollars).

◆Prevent ~€14.3 trillion per year in 2050 global warming costs (2015 dollars) otherwise due to 139-country emissions.

Wind and solar are intermittent diurnally and seasonally, although geographically distributing the systems can substantially dampen the intermittency. However, the advances in materials chemistry and engineering of nano-materials are leading to significant gains in a variety of energy storage technologies. Recent figures on the levelized cost of storage (LCOS) compiled by Lazard indicate the current state of play in the chart below. These estimates are continuously changing targets, with some of the technology costs already further declining over past months.



Source: Lazard (2015) Levelized Cost of Storage LCOS), version 1.0.

The Industry Working Group rightly considers that, given the global market, energy storage is projected to grow to €44 billion by 2020.

End-Use Efficiency-Productivity across Luxembourg Industry

The exergetic efficiency-productivity gains enabling solar, wind and storage to cost-effectively resource the global energy system are of utmost value and timeliness. Just as immense, however, are end-use efficiency gains above and beyond the efficiencies stemming from electrification (displacing thermal combustion). Efficiency throughout the value chain is as great of value and timeliness as solar and wind power.

A key metric and indicator of efficiency is the ratio of energy required to produce each unit of GDP (e/GDP). A quarter century of increasingly detailed assessments point to efficiency as the single largest pool of low-cost, low-risk means of delivering energy services to the point of use.

This mega-growth market opportunity could satisfy half the world's yearly total energy needs for a fraction of the cost of expanding new power supply of any kind. Instead of investing the entire ~€100 trillion for a 100% renewable powered global economy, the same delivered services and benefits could be gained by including efficiency and cutting total costs to €50 trillion.

In addition to €50 trillion of gross monetary savings, there are massive, cost-free circular economy benefits accruing from the dematerialized form of energy services. Metals, minerals and materials are largely substituted by data, information, knowledge and wisdom. Both cases reap €17 trillion in annual direct and indirect savings and health benefits.

Another way to view this market growth in expanding the delivery of energy services in tandem with rapidly diminishing ecological footprints is the following exercise. What would be the economic results if the world averaged 3% per annum energy reductions per unit of Gross Domestic Product (e/GDP) for the rest of the century?

The results would catalyze an immense, expanding pool of prosperous outcomes for citizens, consumers, taxpayers, ratepayers, and businesses across the economy, while also enhancing the biosphere. Efficiency is an emerging market worth many tens of trillions of euros in the offering for TIR-driven enterprises.

John "Skip" Laitner's update of the 2003 estimate prepared by Professor Art Rosenfeld, Lawrence Berkeley National Lab, with estimates to reflect energy projections by ExxonMobil extended to the year 2050, indicate the following results could accrue. The base case assumes the energy per unit of GDP improving at -2% per year through 2040 and continuing at that same rate through 2050. This was compared to a case where e/GDP improves at -3.0% annually through 2050.

TIR GLOBAL ENERGY EFFICIENCY SERVICES MARKET OPPORTUNITIES

Energy Efficiency-Productivity Gains in the 21st Century in

Delivering Energy Services at -3% per annum energy reduction per unit of global GDP

- 12+ TeraWatts per year Savings Potential in 2050
- 220 TW Cumulative 35-Yr Savings [equal to 12 yrs of global total use in 2015]
- € 80 Trillion Gross Cumulative Savings (in 2015€)
- 670 $GtCO_2$ Cumulative Emission Savings (at negative cost)
- € 60 Trillion Avoided Cost of Carbon

The calculations assume: US$360 Billion per TW based on 2015 global GDP $75 Trillion (in constant 2010 USD), 19 TW global energy consumption in 2015, Energy amounts to 8% of global GDP, US$ converted to Euros. Avoided Cost of Carbon based on 2015 Carbon intensity (3 $GtCO_2$/TW), valued at $100 per ton CO_2 Social Cost of Carbon, and 2010 US$ converted to Euros.

Luxembourg Construction, Real Estate, and IOT-GAIN Amplifying

These end-use efficiency gain opportunities are in every sector and value chain of the economy, conjoined with both existing processes and products, as well as with the IoT and GAIN technologies in the process of disrupting even the most durable, long-lasting market performance trends in sector after sector. The global built industry is overdue for such a makeover, given their immense ecological footprint and the extensive exergetic gains that IoT and GAIN technologies can catalyze.

Over time, every existing building and facility should undergo a real-time retrofit and upgrade process that uses wireless smart sensor networks drawing off Big Data and data visualization analytics, transforming energy-consuming buildings and facilities into positive energy high-performance buildings. This is a multi-decadal immense market for Luxembourg's industrial sector businesses to pursue. Given Luxembourg's 4% per annum new construction growth rates, all new construction should also be designed to create buildings that serve as Big Data nodes, micro power generating sites, and electric and fuel cell vehicle transport hubs.

Infosys, one of the world's largest IT companies, provides an exemplary model. The €8.3 billion annual revenue multinational is achieving 80% energy savings in new commercial building construction and operations through its innovative green infrastructure division. Upfront, systems-integrated architectural-engineering designs led to 50% cuts in energy consumption (achieved at roughly no extra first cost), while real-time, life-long "continuous commissioning" of the facilities is maintained through smart sensor networks and Big Data building analytics to ensure the facilities remain operating and performing as designed. These design features resulted in accruing an additional 30% energy savings. Deep retrofits and rebuilds of existing building stock can achieve total savings of 50+ percent.

Architect Ed Mazria, founder of the Architecture 2030 global initiative embraced by business associations and cities around the world, points out that over the next 15 years 82 billion square meters of new building and rebuilt construction will take place in urban areas, amounting to the equivalent of 60% of the world's existing building stock.[192] Visually, imagine another Empire State Building being built every 40 minutes for the next 15 years.

Designing, fabricating, and assembling smart buildings, and measuring real-time operating performance data of the inventory of energy-consuming smart devices (building shell, lights, appliances, electric motors, and onsite power and storage systems) begin with industrial manufacturing.

The TIR architectural design features, construction components, and smart technologies open up vast new opportunities for Luxembourg industry. For example, Luxembourg's Guardian Industries are using advanced manufacturing processes like chemical vapor deposition (CVD) to lay down nano-scale thin films on 'smart glass.' This is just one building shell (and vehicle) component providing valuable climate-adaptive energy efficiency benefits (heating and cooling control, natural daylight). Within the next 4 years the global smart glass market is projected to grow to half a billion square meters per year valued at € 53 billion. In addition to smart glass, the global market for building-integrated photovoltaic (BIPV) is projected to exceed € 5 billion by 2022. In addition to glass, Dupont Luxembourg has a long record of success of promoting a line of building envelope and construction system products used in green and sustainable certified buildings.

The Internet of Things makeover of industrial electric drive systems (motors, pumps, compressors fans) and heat processes, presents another massive global market opportunity for cutting-edge industrial and manufacturing companies. Embedding the industrial electric drive equipment with wireless smart sensor networks enables delivering Big Data for real-time continuous analytic visualization and automated control by rapid response intelligent algorithms. Intelligent factory operations deliver multiple benefits including energy and resource savings, reduced waste, improved product quality, reduced down time, lower capital and operating expenditures, and reductions in emissions and pollution. They are also integral to advancing circular economy outcomes.

Half of all the electricity in the world is consumed by industrial electric drive system components, and over 60% in countries like China. Integrated design and installation of high-performance components can achieve 50+% savings in new installations at or near zero net cost, and 30+% savings in retrofits with a levelized cost of electricity (LCOE) as low as several cents per kWh. China is pursuing large "efficiency power plants" (EFFs) based on this market transformation potential, aggregating industrial and manufacturing sector retrofits, as in

[192] Ed Mazria, Architecture 2030, ROADMAP TO ZERO EMISSIONS, June 4, 2014, submission to Durban Platform for Enhanced Action; citing and Adapted from, Dobbs, Richard. Insights & Publications. 06-2012. http://www.mckinsey.com/insights/urbanizationurban_world_cities_and_the_rise_of_the_consuming_class

Jiangsu Province where 10,000 MWs of electric motor system retrofit savings were identified at a delivered LCOE of 1 cent per kWh.

These exergetic efficiency-productivity gains are foundational to engaging the IoT general-purpose technology platform. Connectivity is key for catalyzing experience and learning curves leading to more innovative manufacturing design techniques and technologies capable of producing smarter products and delivering intelligent services.

This is well-recognized by the Industry Working Group, noting crossover and transversal opportunities with other sectors. Beginning with applied research, development and innovation (RDI) initiatives, and continuing through the co-development of new value propositions and value-added services constituting smart manufacturing initiatives, and going all the way to leveraging circular economy outcomes.

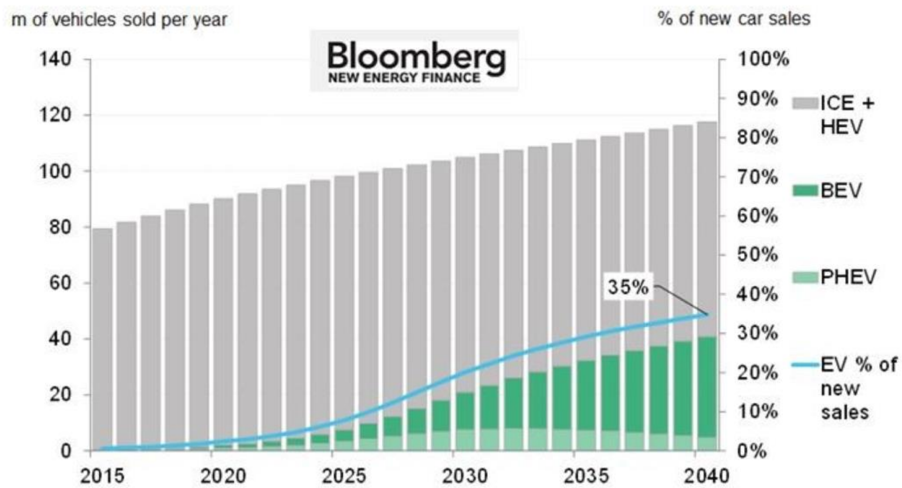
One of the largest transversal possibilities being pursued in Europe, the U.S., China and Japan, is the convergence and synergies of connecting the Communication Internet, the Renewable Energy Internet, and the Transportation and Logistics Internet, and Buildings as Nodes. All of this is undergird by the Internet of Things and smart manufacturing. The emergent IoT/IoS/IoN tools and technologies increasingly enable the linking and interaction between the traditionally silo'd vertical sectors of the Second Industrial Revolution. Large exergetic productivity gains become possible.

Buildings and factories become nanogrids operating in real-time, with plug-in electric vehicles serving as connected picogrids (detachable, portable, interoperable). The nanogrids connect, in a self-similar fractal-like pattern, into neighborhood microgrids, which, in turn, link together to form urban-wide minigrids. Cities fractally link together to form regional macrogrids, and these macrogrids form the backbone of continent-wide smart supergrids. This fractal growth pattern, facilitated by embedding IoT connectivity throughout the industrial and manufacturing processes and products, achieves leaner production while enhancing resilience. Local nanogrids and microgrids remain functional eand resilient even in the event of large-scale failures of the supergrid or a regional macrogrid due to a cyber-attack or natural disaster.

Chemicals and Automotive Sector

Luxembourg vehicle-related companies like Delphi and Goodyear, and logistics companies like CFL, Dematic and Cargolux have key roles to play in the growth of digitalized Transportation and Logistics Internet. Delphi, a leader in powertrain electrification, has decades of experience marketing a robust hybrid & electric vehicle product portfolio: charging systems, connection systems, electrical centers, energy storage systems, power electronics powertrain systems, thermal systems, service solutions, and wiring assemblies. The most recent forecast by

Bloomberg indicates electric vehicles will constitute one-third of global new vehicle purchases within the next 25 years, as shown in the chart below. The projected sale of 41 million EVs would be nearly two orders of magnitude greater that the 0.4 million EV sales in 2015.



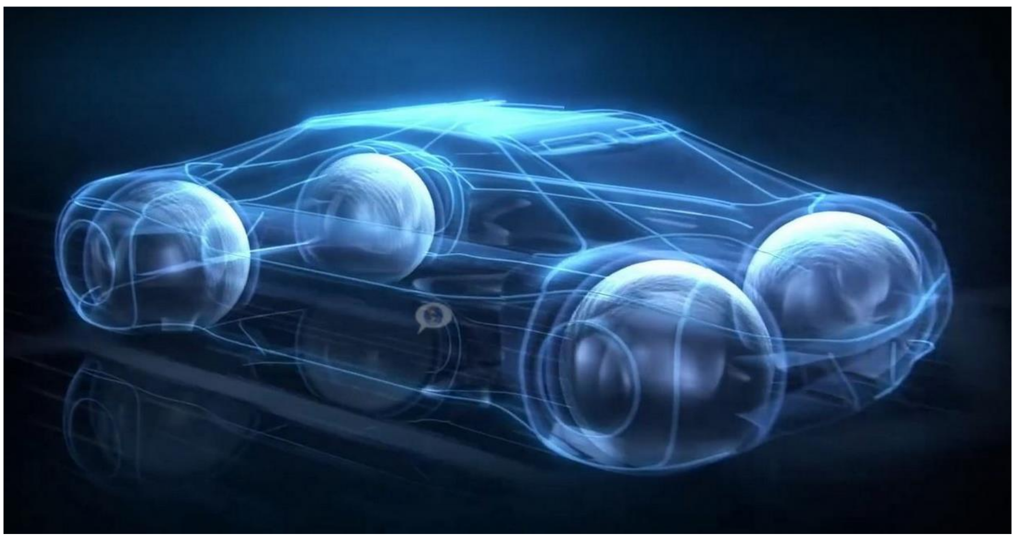
Source: BNEF (2016) Electric vehicles to be 35% of global new car sales by 2040.[193]

Goodyear has tantalized the world with an imaginative concept rendering of what the tire of the future may become in the world of autonomous/driverless electric vehicles. The Eagle-360 visionary tire (sketch below) is designed as a sphere that enables maneuverability in any direction, such as driving sideways into a parking space. Embedded sensors would help balance wear and extend travel life by constantly rotating the tires, and sensors would also monitor pavement and weather conditions and communicate the information via telematics to surrounding cars. Goodyear envisions magnetic levitation serving as the vehicle's suspension, propulsion and steering systems. Magnetic fields would be used to suspend the tires, preventing them from making vehicle contact. 3-D printers produce the tire treads, which Goodyear believes could allow customizing tire treads for the specific region where the vehicle resides.

Goodyear's IntelliGrip is a near-term concept tire, also loaded with sensors and being designed as an integral control component system of autonomous vehicles. Ten million self-driven

[193] BNEF (2016) Electric vehicles to be 35% of global new car sales by 2040, Bloomberg New Energy Finance, February 25, 2016, http://about.bnef.com/press-releases/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/.

vehicles are projected to be on roads by 2020, and Boston Consulting Group estimates the market value could exceed €36 billion by 2025. More than 100 million driverless vehicles could be on roads by 2035. Goodyear sees the IntelliGrip sensor-packed tire concept performing a key role in communicating driving information to other drivers. The sensor smart algorithms would perform a range of functions: sense pavement and surrounding road conditions, weather circumstances, monitor tires for wear, and monitor air inflation levels. Linked to GPS and telematics devices, the tire could also perform smart city tasks such as mapping street potholes, and providing real-time data to city transportation departments for repair.



Source: Goodyear, Eagle-360 spherical concept tire.

DOMESTIC LEARNING CURVE BUSINESS MODEL INNOVATION (BMI)

Luxembourg's Industry sector – constituting nearly 5% of the nation's GDP, and depending on exports for 85% of its revenues – needs to implement a dynamic, continuously evolving Business Model Innovation (BMI) process. IoT demands no less, in order to future proof the sector's ongoing innovative performance, value creation, differentiated products and services, market position and profitability.

Luxembourg's domestic market and the region's surrounding markets provide the crucibles for experimenting with marketing creative and innovative applications and solutions for the convergence of the Communications Internet, the Renewable Energy Internet, the automated Transportation and Logistics Internet, and buildings serving as nodes and nanogrids. This trial-and-error process helps accrue tangible outcomes, learn from mistakes, and accelerate the learning and experience curves in scaling up IoT-based products and services.

Exporting Products, Expertise and Knowledge-as-a-Service

The Industry Working Group views public-private partnerships as the cornerstone in pursuing and advancing the myriad aspects constituting the Third Industrial Revolution and the Luxembourg industry sector becoming a leading international platform. More than 80% of Luxembourg's exported goods flow into other EU countries (55% to the three surrounding nations of Germany, France and Belgium). These regional trade partners simultaneously pose both challenges and opportunities.

The challenges stem from competition by other EU nations in pursuit to varying degrees of TIR growth opportunities, also focusing on energy and resource efficiency, RDI and Smart Industry venues. The flip side of the coin, however, is the opportunities rooted in the EU's collective vision and manifest policies, programs and initiatives which strongly promote the TIR economy throughout the EU. The Industry Working Group recognizes this upside, both for leveraging available financial resources, as well as exploring partnership opportunities for growing exports within and beyond the EU.

With accumulating experience and learning curves in using IoT/IoS/IoN platforms and GAIN technology innovations, one of the core advantages is increasing the intellectual/intelligence capital, along with advancements in human and social capital, that are the prerequisites for creating Knowledge-as-a-Services expertise as an export business model innovation.

The fractal metaphor is apt in conceptualizing this export growth potential. Local and regional transformation of buildings into nanogrids, with EVs as picogrids, connected together in a fractal-like manner, becomes a replicable export business model; packaging together integrated smart products and skills with Knowledge-as-a-Service expertise.

Re-Skilling & Up-Skilling for the TIR

Like previous industrial revolutions, TIR induces movements towards de-skilling. Digitalization, human/intelligent machine interface, Big Data analytics, advances in robotics, and automation will displace, destroy and create new jobs. There is no consensus on the percentage of job destruction due to these changes (it varies between 12% in Germany for ZEW estimates[194] and 50% in Luxembourg or Germany for Bruegel calculations[195]) but it is crucial to invest in

[194] Bonin, H., Gregory, T. and Zierahn, U. (2015) "Übertragung der Studie von Frey/Osborne (2013) auf Deutschland", *Kurzexpertise* Nr. 57, ZEW (Zentrum für Europäische Wirtschaftsforschung), http://ftp.zew.de/pub/zew-docs/gutachten/Kurzexpertise_BMAS_ZEW2015.pdf

[195] Bowles, J. (2014) The Computerisation of European Jobs, *Bruegel*, http://bruegel.org/2014/07/the-computerisation-of-european-jobs/.

education and life-long learning to give high skills to workers and allow them to be adaptive to changes and remain employed. Complementary measures need to be taken: to up-skill workers to be reactive to advances in technology and robotics; to re-skill workers losing jobs due to TIR changes; and to give future workers the high skills needed for the new jobs created by the TIR. In the short and long term: forecasting of occupations, qualifications and skills needed for jobs impacted by TIR."

In discussing the Digitizing of European Industry, the European Commission points out that 90% of jobs in the near future will involve digital skills. In the ICT profession alone, more than 800,000 unfilled positions are projected over the coming four years.[196] The advancements in smart manufacturing, and the digitization, robotization, and Internetization of industry requires a steady stream of digitally savvy workers and ICT-educated professionals in the metals, chemicals, electronics, and construction sectors.

PROPOSALS

1 Business Model Innovation

1.1 Leverage and empower the "Haut Comité pour l'Industrie" [High Committee for Industry] to develop an industrial eco-system. The "Haut comité pour l'Industrie" is an established national committee with high representatives from the government, industry and research. The mission of the "Haut comité" is to assure regular exchanges between members of the government and experts from the industrial sector with the objective to safeguard and support the existing industry; to create an environment conducive to help establishing to new industrial activities; and to support industrial actors active on the international market and to identify new activity niches. The "Haut comité" has an in-depth and holistic overview of the current state, the opportunities and challenges faced by the Luxembourg industry. The "Haut comité" would be a great platform for the main actors to meet regularly and to set the priorities for the development of an industrial eco-system. Stakeholders include companies, actors in RDI, government agencies, and the Business Federation Luxembourg (Fedil). The challenge will be empowering the various working groups to make concrete proposals on their specific topics. Resource requirements include human resources in RDI, and financial resources to sustain promising projects.

[196] EC (2016) Skills and Jobs, Digital Single Market, Digital Economy and Society, European Commission, April 14, 2016, https://ec.europa.eu/digital-single-market/en/skills-jobs.

1.2 Establish a BMI platform for facilitating ongoing communication and interaction between diverse industry professionals regarding TIR and Smart Industry / IoT opportunities, changes, and actions.

1.2.1 Internet-based communication platforms are essential collaboration and innovation tools for sustaining networking on initiatives and projects set up intra-firm across functions (RDI, accounting, IT), inter-firm, and between sectors (buildings, grids, mobility).

1.2.2 More knowledge can be communicated and retrieved more quickly, thoroughly, widely and cheaply, while enabling ongoing sharing of comments and ideas.

1.2.3 Moreover, IoT tools enable communication represented and presented in a rich diversity of ways (text, spreadsheets, data visualization, videos, audio, animated walkthroughs, 3D virtual reality and augmented reality experiences, etc.), as well as allowing for rapid formation of self-organized ad hoc working teams with specific missions or goals.

1.3 As part of or in parallel with the BMI platform, set up a data-driven, visually mapped, inventory of exergy opportunities. This exergy platform would take the form of compiling all of the energy, water and resource consuming processes and equipment in the industry sector.

1.3.1 This is the first key step in developing a living roadmap and action map for implementing exergetic efficiency-productivity gains. It is also core to initiating an industry-wide Knowledge-as-a-Service expertise as an export business model innovation.

1.3.2 One major caveat, exergetic gains always should be examined and applied from a systems-integrated perspective rather than by focusing on single pieces of equipment or artificially constrained limited packages of equipment. For example, avoid using smaller-sized piping laid out with sharp (elbow) turns in favor of lower friction larger-diameter pipes laid out straight and minimum turns. This system vantage point results in the reducing the size and number of necessary motors, pumps, and compressors to deliver the same chiller service with lower capex and opex.

1.3.3 At the office building scale, where U.S. utility sponsored energy efficiency retrofits average 18% savings, a system-integrated deep retrofit can achieve 80+% savings. Many of the savings that are cost-effective in the deep retrofit would not be cost-effective if only considered as a stand-alone option. For example, upgrading windows with ultra-efficient glazings are costly, but cost-effective as a result of savings accruing from the need for a smaller, less costly chiller system.

1.4 Use the BMI exergy data visualization platform to examine opportunities for making aggregated purchases and procurement of high-efficiency equipment upgrades, as well as installing onsite and distributed solar, wind and storage systems acquired at closer to wholesale cost. The learning curve in aggregated purchasing becomes an integral part of Knowledge-as-a-Service.

1.5 Use the experience process gained from establishing the BMI exergy data visualization platform to perform similar "Knowledge-as-a-Service" inventories for domestic and regional public agencies, educational institutions, commercial and agricultural facilities, and residences.

1.6 Use the BMI platform for Industry professionals to map domestic and export market opportunities for efficiency, wind, solar, and storage technologies. This should encompass potential partnerships, as for example, ArcelorMittal working with Siemens and Statoil on constructing offshore wind parks. Partnering with Luxembourg's financial and insurance sector would greatly augment the Knowledge-as-a-Service expertise export BMI.

1.7 Industries should be encouraged to use all available free space on the roofs and in parking lots to produce solar energy which they can either return to the power grid or use for self consumption.

2 Technical

2.1 Develop technology platforms for co-located industry and university researchers working on common transversal issues (enabling).

- High potential domains include: IPCEI on High Performance Computing and Big Data Enabled Applications (FinTech, Smart Space, Smart Agriculture, Smart City, Smart Energy, Smart Water, Smart Building, Smart Mobility, Personalised Medicine, Smart Manufacturing, Smart Materials, Civil Protection); Robotics (broad scope e.g. small flexible robots, ergonomics, AGVs, lifting, pick&place); National Additive Manufacturing Centre; National Composite Centre; Automotive Campus; Smart Industry.

- Align national research with needs of industry and other beneficiaries, to foster serendipity innovation, risk sharing of research and innovation, and mutual learning.
- Bridge the valley of death (Technology Readiness Level 4-7, i.e. between research and industrial applications), by aligning Luxembourg 'Smart Specialisation' (RIS3, http://s3platform.jrc.ec.europa.eu/regions/LU) with national priorities in the research and industrial sectors.
- Promote complementary multi-industry public-private-partnerships, with stakeholders to collaborate on common topics with governmental and financial (public and private) support.
- Address Transversal issues, including: cross-sectorial, cross-application products and services; overcome missing critical mass in product/service lines; valorize innovation in different industrial applications, market segments, and sectors.
- Launch lifelong learning programs tailored to the need of industry and competences of University of Luxembourg researchers.
- Set up enabling technology platforms to facilitate cost reduction of RDI through mutualisation (sharing) of resources (researchers, equipment, facilities, etc.); develop new applications and provide foundations for innovation (proof of concept, scale up, industrial transfer, mass production) through equipment, pilot lines, enabling platforms, technology, and infrastructure. Challenges to be faced and sub-measures to be taken into account include: overcoming the difficulties of upfront investment from private industry when thre is no direct return on investment: garnering public support to put initial technology platforms in place and have the private sector contribute in the second phase. Other challenges that need addressing: multi-partner PPPs are quasi non-existent; there is lack of critical mass in multiple markets, sectors, and domains; the EC state-aid rules are becoming more stringent; low private financing of 'risky' projects; high capital investment for equipment; trouble filling gaps in national value chains (Foreign Direct Investment); and the need to create start-ups to valorise innovation, IPR. The cities of Aachen and Grenoble are readying initiatives to set up successful Eco-systems for research cooperation.

2.2 Establish a platform for engaging relevant professionals across sectors in identifying, prioritizing, and addressing the myriad of technical challenges associated with scaling up Smart Industry, and seamlessly interfacing with the Internets of communication, renewable energy, mobility & logistics and buildings as nodes and nanogrids.

2.2.1 Standards and protocols are important for ensuring a range of attributes, from interoperability of system components and devices, to disassembly for circularity at end of useful lifespans.

2.2.2 Countries have taken different approaches, whether like Germany's lengthy procedure engaging stakeholders to establish IoT standards and norms, or on the other hand, the more open-ended approach found in the United States, where rapid development is pursued with reliance on evolving de facto protocols.

2.2.3 The open source platform will enable an ecosystem to emerge and evolve, reflecting the myriad of generic and specialized technical issues around which triple and quadruple helix knowledge networks can form sub-working groups.

3 Regulatory

3.1 Establish a quadruple helix knowledge network for business to engage with government, academia and key stakeholders for identifying needed changes in superseding regulatory impediments with regulatory innovations.

3.1.1 Many public utility rules, planning methodologies, regulatory policies and financial incentives are still designed to promote large-scale expansion of fossil and nuclear power plants. Many of these were never designed for, and now become impediments to accelerating the scale-up of demand-side, IoT-based energy and resource efficiency improvements, onsite and distributed solar, wind and storage, or the bidirectional interoperability of buildings, electric vehicles, and power grids.

3.1.2 To overcome the inertia shown to be the case among most public utility regulatory agencies, a quadruple helix knowledge network can play a formative role in pushing for essential changes.

3.2 Blockchain technology should be assessed and pragmatically integrated into Industry operations for performing a variety of functions. As a distributed ledger tracking transactions, protected by strong encryption and authentication, yet accessible for auditing purposes, blockchain already is widely used by banking, financial and insurance firms. But its application across the economy is now being experimented with and employed.

3.2.1 One potentially large function is using blockchain in tracking bidirectional energy transactions, as with onsite and distributed solar, wind, and energy storage systems, connected to smart-metering systems. It could serve as the underpinning of a burgeoning prosumer energy service market.

3.2.2 Blockchain also is currently being explored for measuring and verifying resource, pollution and waste flows, providing key metrics for advancing the circular economy.

4 Public Policy

4.1 Develop and promote the industrial scale recovery of critical raw materials from electronic scrap or production residues collected around the world. Terrestrial resources of critical materials and rare earth metals are limited and will be depleted or increase steeply in cost over the next few decades at current world economy growth rate. The EU CRM list includes 20 critical materials (antimony, beryllium, borates, chromium, cobalt, coking coal, fluorspar, gallium, germanium, indium, magnesite, magnesium, natural graphite, niobium, PGMs, phosphate rock, heavy REEs, light REEs, silicon metal and tungsten). Recovery from scrap and residues is also an integral component of the circular economy idea pursued by the TIR initiative, as well as integrating into the activities of the transportation and logistics hub. This expands competitive technology edge opportunities for Luxembourg's industry, university, and public and private research opportunities, as well as attracting new business in this highly technologized field, including first mover opportunities for some rare metals processes that are not yet developed or at pilot level. It will also create a large number of lower qualification profile jobs involved in transportation logistics and disassembling/segregation of electronic scrap.

4.2 Set-up smart spatial planning and management of business sites (industrial and commercial zones). Digital GIS visualization tools are essential for making the best use of energy and materials and achieving zero waste and pollution targets through industrial symbiosis and enhanced logistics. Examples are legion, highlighted by the following opportunities: avoiding unnecessary transportation of people and goods; closing material loops by being energy efficient at every level (individual businesses, business site level, and at a national level); promotion of smart regional planning of business sites and integrated designs of business parks with long-term added value for the economy, the environment and society; mapping existing heat sources ('waste heat'), quantifying untapped material flows (waste, off-gas and wastewater) and optimally matching these potential opportunities with needs of new businesses (closed loop energy and material flow management systems); creating energy services from on-site renewable energy sources; managing and distributing energy via smart grid solutions (including energy storage solutions); making sure business site management entities will be put in place (e.g. syndicates); making use of brown fields instead of high quality arable land or valuable ecosystems; ensuring good connection to public transport and logistics hubs; foreseeing buffer zones between planned business sites for the manufacturing industries and existing settlements to avoid nuisances; limiting excavation depth during construction to avoid excessive excavation waste, making use of sustainable water management practices (minimizing sealed surfaces, favoring green roofs and walls, and planning sustainable rain- and wastewater management systems); enhancing cooperation between businesses (e.g. raise local funds to be spent locally to improve business park); planning joint facilities (meetings rooms, canteens, mobility solutions, technical equipment, etc.); developing multiple and flexible uses of a site that allows adapting to future needs; actively involving local or neighbouring population and future users in planning phases to increase acceptance and avoid or reduce future conflicts; planning buildings as 'material banks;' and taking a human-centered design approach by fostering ergonomic architecture and techniques, integrated landscaping, and facilities to accommodate the combination of professional and private life. There are a number of inspirational resources including knowledge assets and know-how that can be tapped and whose results can be leveraged in the pursuit of future activities.[197]

4.3 Engage in a quadruple helix knowledge network between business, government, academia and key stakeholders to identify and prioritize the national, regional and EU-wide changes that Luxembourg's leaders should promote.

4.3.1 For the Industry sector, the transaction costs and risks of developing and exporting IoT and Smart Industry driven products, expertise and Knowledge-as-a-Service into other markets can be mitigated by promoting generic adoption of innovative public utility regulatory reforms, planning methodologies, and how returns on energy investments are calculated, and removing policy barriers and regulatory impediments for accelerating the scale-up of TIR tools, technologies, products and services.

5 Financial

5.1 Technology platforms need substantial investments: e.g. National Composite Centre 100 million Euro over five year period (50% public / 50% private), IPCEI on HPC and BDA: H2020 programs totaling over 6.7 billion Euro 2018-2020 (European public funding). Benchmark

[197] A few illustrative resource examples include: Cradle to Cradle in Business Sites (http://www.list.lu/en/project/c2c-bizz-1/); EcoQuartier (http://ecoquartier-miroir.eu/index.php/home); Luxembourg Industry Thermal Heat Map (http://www.heatmap.lu/); Kalundborg Symbiosis in Denmark (http://www.symbiosis.dk/en); London Sustainable Industries Park (https://www.lbbd.gov.uk/business/growing-the-borough/our-growth-hubs/london-sustainable-industries-park/); Strijp T in Netherlands (http://www.c2c-centre.com/project/strijp-t-pilot-project-c2c-bizz; Park 20|20 near Schiphol, Netherlands (http://www.park2020.com/) Solarwind (http://www.solarwind.lu/).

references: Multi-domain includes Campus Aachen (RWTH, Germany), CEA-Tech (Grenoble, France); and, Focused: National Composite Centre (Bristol, UK), Automotive Campus (Helmond, Netherlands), and HighTech Campus (Eindhoven NL).

5.2 Build an acceleration program for start-ups whose vision it is to build products and services aimed at reducing carbon footprint or other environmental benefits. Innovation is the battleground of the future. Luxembourg is focusing on building an entrepreneurship ecosystem in which both the public and private sector work hand in hand to facilitate and support the emergence of new innovations through the creation and development of startup companies. Thus it is of great importance that we build an acceleration program that would identify and support the most innovative ideas in the field of start up eco-innovations. The objective is to run the program for 3 years, with 10 companies/teams selected each year from at least 100 projects received. From 30 companies selected over three years (i.e., 2017, 2018 and 2019), 12 should have survived and developed by 2025. The focus of the companies should be global with high growth potential. Combined revenues should be 120 million €- with an average 20 per cent EBITDA. Combined Tax revenue in 2025 – 4.3 million € (assuming a profit before Tax of 16.8 million € and an average tax rate of 25 %). 500 jobs will have been created. The impact on the environment should be measurable - products and services should reduce energy consumption by 30% of the processes they will be employing globally. Stakeholders should include: Ministry of the Economy (Owner) – Fit for Start Program; Ministry of the Environment; Nyuko/Technoport; International Experts and Mentors; Lux Innovation – Fit 4 Start Program; University researchers, etc. Startups selected would receive 50.000 €. Resources needed: total budget over 3 years- 1.5 million €. Expenses for international mentors, training and client engagement services: Accelerator program would include the facilitation of 150 meetings with potential clients over a 3 month period; Lean Canvas Methodology- 200 € a year- Total 600.000 €). Total expenses for the 3-year program: 2.1 million €. Companies would be able to pitch for additional funds once they see sales traction – through accessing additional funding or pitching to the Eco Innovation Seed Fund – 20 Million € endowment. (See measure: "Develop a private equity investment fund for industry oriented projects and companies in Luxembourg").

5.3 Develop a private equity investment fund for industry oriented projects and companies in Luxembourg. When developing a vision for the "Industry" Pillar in the Third Industrial Revolution Lëtzebuerg, the working group identified an absence of seed and venture capital for industry projects and companies. We see three specific types of needs: 1) Spin-offs from Research and Industry lack offers for seed capital in conjunction with existing managerial support (e.g. LuxInnovation) (equity needs of approximately 0.2 – 1.0 Euro million per project); 2) Luxembourg's industrial companies lack equity providers for growth projects (especially if companies cannot meet balance sheet requirements of commercial banks – equity needs of approximately 0.5 – 5.0 Euro million per project); 3) Foreign direct investors sometimes need equity providing partners in Luxembourg aside from strategic industrial partners (equity needs of approximately 1.0 – 10 Euro million per project). A private equity fund focused on industry would assist companies that are working in the industrial sector in their growth projects. This would accelerate growth of Luxembourg's industrial activity. The setup of a private equity investment fund can be accomplished in approximately 10 months. The following development phases are foreseen: a) Developing a strategy paper for the fund (fund strategy, ideal investors, ideal projects, project funnel, industry focus, management structure, etc) –Months 1-3 b) Marketing of the fund towards principal stakeholders including potential investors – Months 4-6; c) Preparation of operations (recruiting management team, defining main processes, marketing of the fund towards the public, etc. – Months 7-9; d) Operational start of the fund – Month 10. Involved stakeholders include: The Luxembourgish government aims to increase the percentage of industrial production within the nation's gross domestic product. Universities and research institutions have an interest in spinning off technical businesses and ensuring their success. Companies have an interest in finding adequate funding for their growth projects. Business consultants (coaches for start-ups and entrepreneurs) and semi-public institutions (e.g. LuxInnovation) have an interest in helping entrepreneurs to finance, set up, and grow their business (ideas) by developing their strategies and partner networks. Key challenges are: 1) securing investors of the fund; 2) developing a partner network that identifies projects and fills the project funnel; 3) recruiting a competent management team; and, 4) engaging a competent advisory board that acts in the interest of the fund. Resources needed: A first fund should have a capital of approximately 15-30 million Euro, depending on the investment project mix, to be invested within approximately three years. Project exit should be possible within three to five years. A management team requires an industry specialist and a private equity fund specialist, plus support (approximately 0.5 millon Euro expenses per annum).

5.4 **Partner with the financial and insurance sector in setting up an Internet platform, incorporating a triple or quadruple helix knowledge network with government, academia and other stakeholders, to examine the range of financial instruments that can be applied for accelerating Smart Industry start-ups, scale-ups, and expansion of domestic and export business model innovation.** Disruptive start-up opportunities should be examined for within existing companies (e.g. a skunks work) and new ones.

5.4.1 Preferably, as with all of the other proposals, the objective is to align initiatives so that the accumulated learning curves and experience curves provide spillover, crossover and transversal benefits.

5.4.2 A large and expanding portfolio of public and private financial tools have become available, spanning a broad range of discount rates, IRR requirements, diversified risk strategies, differing timeframes, and levels of financing.

5.4.3 Familiarity with and experience in using these diverse financial instruments is a valuable component of developing an IoT-based Knowledge-as-a-Service.

6 Educational

6.1 **Make companies fit for digitization (Internet of Things, IoT); define support measures – check if R&D support measures are available (e.g. the new R&D law) for digitization of production process.** A set of disruptive digital technologies will transform the manufacturing industry. The digitization of the manufacturing sector will become a reality and a challenge for industrial companies. It is, at the same time, an opportunity for the local players to render their production more efficient, to save on resources, time, money and energy and to focus on the real added value. Therefore, technical guidance and financial support will be needed, especially for SMEs. Stakeholders to include: companies, Fedil, Luxinnovation, Chambre de Commerce, and the Ministry of Economy. Challenges include raising awareness among companies that digitization of production processes has become a reality. Give guidance on: How will digital disrupt existing industries/business models? Where should a company make investments in infrastructure, cybersecurity, and partnerships? Build use cases/showcases (IoT/Digitization of production process) to demonstrate to companies what is possible and feasible, through PPP projects, e.g. LIST, University plus three to five companies. How to handle the huge amount of data collected? How to make value out of it? For example: “Big Data in Manufacturing”; sensitive robotics; energy and resource efficiency, etc. What can be the role of the existing Learning Factory (http://www.learningfactory.lu/)? Educate students and industry in “Operational Excellence.”

6.2 **Expand re-skilling and up-skilling workers in a digitalized and automated work environment.** Investment in initial education to provide future workers with the high skills needed to leverage technology advances. Reform of the vocational training policy to ensure ready access to retraining services so that every employee has a fair shot to react to evolutions induced by the Third Industrial Revolution. Stakeholders include the government which needs to invest and initiate reforms in initial education and vocational training to make the system of education and life-long learning fast enough to race ahead with machines instead of racing against them; social partners who need to actively participate in the anticipation of future needs and in the reforms of initial and vocational training policies; businesses that need to anticipate the re-skilling of their workers; and universities (science, technology, and engineers) need to offer related education programs (Bachelor, Master, PhD, life-long learning). Challenges to be faced and to be taken into account include: Now, the employees who participate most in trainings are the highly qualified ones. It is necessary to: enable each employee to obtain a diploma, a professional qualification or certification to grow professionally through life-long learning, career enhancement periods, Validation of the Acquisition of Experience (VAE), etc. and ensure the access of all workers to skills training by removing access barriers (especially for low skilled ones): reduce training registration fees; adapt work organization and provide periods dedicated to up-skilling training. Create critical mass, e.g. in robotics by combining skills and competencies of universities of the greater region (Lux, Saar, Lorraine, Wallonia) to provide industry with a comprehensive offer in advanced industrial robotics. (offering tailored research and in-depth education) - Expand the offer of vocational training and increase the responsiveness of the vocational training policy to changes that will occur with the TIR. The National Training Centre (CNFPC) need to constantly adapt the training offer and provide more continuous training programs targeted for industry. -Develop "work based learning" actions with a close relationship between enterprises and the formal education system. Resources required include: Given the social nature of the measures to be implemented, a public co-funding is needed to invest in initial education and vocational training. The creation of a joint fund for training in industry is encouraged to complement existing financial mechanisms in vocational training. Adaptation of existing legal texts that are not mixed: collective access (1.) on one side and individual access (2.) on the other side: 1. Continuing vocational training: social partners agreement (2nd May 2003) and the Grand-Ducal Regulation (30th March 2006); 2. Law of 24th October 2007 that gives rights to employees to take leave for individual training.

6.3 **Help educators design new curricula that incorporate the kinds of new aptitudes, skills and competences vital for IoT specifically, and the TIR more broadly.** Curricula should include increasing intellectual capital through the STEM subjects (science, technology, engineering, maths), as well as enhancing human and social capital skills through team learning, brainstorming, communication, and designing and carrying out diverse projects.

The curricula should not be limited to classroom instruction, but include onsite apprentice programs, real-world field experience, and online collective intelligence networks (COINs).

6.4 Young people are rapid adopters of IoT technologies through gaming, social media, and imaginative play and creation with 3D virtual reality and augmented reality devices (and soon additive manufacturing with the availability of lower cost 3D printers). Teachers are less likely to be as conversant as students with many of these IoT technologies. Cultivating sophisticated and advanced skills, then, in the use of the myriad IoT/IoS/IoN tools and technologies, should be developed through peer-to-peer initiatives, as well as through reverse mentoring venues. Reverse mentoring is on the uptake in business, where new young IoT-savvy employees are being paired in reverse mentoring situations with IoT-challenged veteran employees and senior executives. An initiative with the aim of promoting jobs in industry will start soon in Luxembourg: http://www.hellofuture.lu/.

7 Research, Development & Innovation

7.1 Foster innovation and R&D in the field of temporary energy storage. Use the example of Luxembourg to progress in the development of advanced technologies for temporary energy storage, including energy conversion at high efficiencies as well as the development of energy recovery or multiple use of energy (e.g. use off-heat generated by cooling processes to heat buildings or fresh water, etc.). Industries could play a very important role in the balancing in the grid while more unpredictable productions come to the market and while storage capacities remain limited. Industry could operate fuel switches or react thanks to flexible production levels and connected flexible production installations. Common projects and actions have to be developed with industry. The main challenge is the development of new technologies, which allow a reversible conversion at highest efficiency between different types of energies, as well as storage and recovery without losses. Infrastructures required for these processes have to be at affordable costs (investment and operation). Beyond this, so-called “smart grid” approaches, namely including small unit power generators (few MW), which can further help to compensate the imbalance between the global consumption and production, remain to be further developed and could be part of the project focus. As transportation and logistics represent a significant percentage in Luxembourg’s global energy consumption, these aspects could be included as well. Develop a precise common vision amongst all stakeholders and define priorities in the technical R&D efforts. Set-up a shared fund and fund management system. Gather a competent global project directors team, consisting of technical experts and other stakeholders. Set the right incentives for the industry as a "user" and "developer" of storage technologies. Investors could be public-private partnerships, including the main industrial players (in their role as energy consumers). Main R&D resource for the technical development could be start-ups developing new processes and business models (many of them are already working on the topic). Developing approximate total investment estimates will require the input of experts of the field (e.g. via consulting companies).

7.2 **Spearhead an applied RDI joint consortium on ecologically sustainable, circular economy-based on additive manufacturing and 3D printing resources and production processes.** With strong support by the government, Luxembourg's research institutes in manufacturing innovation in specialized industries should expand their leadership into advanced green, clean and sustainable AM and 3D printing processes and resource materials.

7.3 **Promote Smart Building Materials, with the research financed by both private and public funds.** The construction sector has to meet very high standards as regards the energy efficiency of buildings. Unfortunately, many of the building materials used to achieve this goal have a poor environmental performance, as their production process is highly energy intensive and their recycling is often troublesome if not impossible. A notable example is expandable polystyrene (often referred to as "styropor") used to insulate the facade of a building. An assessment evaluating the environmental impact of the use of such a product would reveal its negative effects relating to the volume of energy needed to produce it and the problematic disposal of it one its life cycle has come to an end. A link can also be made to the work of the WG "Buildings," suggesting entirely new ways to build houses. "Lego-based architectural design concept defined (buildings that can be almost entirely rebuilt based on the same materials, fully disassembling)." This idea is different from the one mentioned above but it can be seen as a complementary element of a strategy aimed at making the building process smarter. Luxembourg could create a cluster comprising both the industrial and the construction sector as well as public research institutes to develop and ideally produce building materials which meet, or even exceed, the required efficiency standards while their production process is less energy consuming and which are 100% recyclable.

7.4 **Engage research faculty and students to undertake applied research initiatives such as the BMI proposal to develop a real-time data inventory and visual mapping platform of all the energy, water and resource consuming equipment and processes in industry.** Students and faculty gain real-world applied research experience, strengthen their aptitude and competences, and help generate knowledge assets that other faculty and students can build upon.

7.5 Create a technology roadmap for Luxembourg.

7.5.1 Advanced Robotics: robotizing mass production. The production of CAD (Computer-aided design) should automatically be implemented without losing time (ongoing research).

7.5.2 Computer Modelisation: modeling products and simulating their behavior, employing the rich portfolio of data visualization, 3D virtual reality, and augmented reality tools.

7.5.3 Rapid Prototyping/ Additive manufacturing: create a prototype with physical properties similar to the final product, in order to reduce concept-to-fabrication costs and time. The fabrication of finished products with complex shapes could be realized.

7.5.4 Open Innovation: promote the open innovation process by designing the collaborative innovation network (COIN) platform to be open source, open access, and open device, and foster the externalization of research and development by including partners, clients and suppliers.

FINANCE

OVERVIEW

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Luxembourg is an important financial center at the heart of Europe. Banks, Investment Funds, Insurance and reinsurance companies and a multitude of specialized service providers use Luxembourg as a hub to provide banking services, asset management, corporate lending, fund administration and cross border distribution to a wide range of international private and institutional customers. Luxembourg's state of the art infrastructure encompassing a high quality legislative, regulatory and supervisory framework places its financial center at the forefront of innovation.

The convergence of the Communication Internet, Renewable Energy Internet, and automated Transportation and Logistics Internet, atop an Internet of Things infrastructure, enables the financial sector in Luxembourg to reinvent financial services in a smart digital Third Industrial Revolution economy.

The emerging "Finternet of Things" (the Financial Internet of Things) will transform every aspect of financial services, foster new business models, and reshape the industry over the course of the coming decade. Financial services, more than any other industry, relies on the collection, analysis, and transfer of data. No wonder industry analysts view the IoT as a game changer for the financial services sector. Sensors connecting every device across the value chain will generate Big Data in every sector of the economy, giving banks, other financial institutions, and insurance companies a steady flow of vital economic data in real time. The data can be mined with analytics to create algorithms and apps that will allow the financial services industry to increase aggregate efficiencies and productivity and reduce transactional and marginal cost in back office functions, the delivery of services to customers, retail payments, investment advice, investment decisions, and trading by algorithms. The IoT will also enable banks to issue virtual currencies.

As a financial powerhouse, Luxembourg has the unique opportunity to strategically consider financial services that could facilitate and accelerate the transition to a digitally interconnected Third Industrial Revolution economy. Critically, such reinvention undergirds a strategic reimagination of Luxembourg's fundamental infrastructure components; communication, energy, mobility, buildings – all are now subject for a digital transformation. The potential of such application is considerable. For instance, initial assessment reveals a nationwide €5.8 billion self-financing investment opportunity in building energy efficiency and rooftop solar energy alone. Similar investment levels could be applied in other sectors of the economy. Indeed, Cisco reports that the digital transformation may drive "US $1.3 trillion of value at stake in the financial services industry." This, in turn, can facilitate many other major investments and market transactions that will benefit the economy as a result of lower costs of energy services.[198]

Future data management and digital technology infrastructure are positioned as key components of the transition to a TIR economy. Intelligent linking of the various technologies (e.g., microfinancing, blockchain, crowdfunding, digitalization of infrastructure) can accrue knock-on benefits that accelerate the TIR transition. For instance, energy efficiency efforts can benefit from technologies that allow for real-time, digitalized data production regarding energy consumption and precise calculation of avoided energy use through energy conservation measures. Real-time data can, for example, pin-point peak shaving opportunities, harvest additional energy savings, ensure investor confidence due to enhanced data analytics, and diagnose any potential energy saving shortfalls. [199] As such, data could both enable savings and automate the measurement of actual whole-building energy savings across a portfolio of aggregated end-users. A big part of the promise of the new approach is its power in scale and precision.

The maturation of the Internet has also spawned innovative new funding mechanisms including crowd funding and micro currencies. With crowd funding, originators of a project put their plan up on a site and pick a deadline by which the necessary funds have to be raised. If the goal is not reached by this deadline, no funds are collected. This provision ensures that the project has enough financing to at least make a go of the venture. Various crowdfunding platforms offer different forms of compensation. Donors can either pledge funds as gifts or receive the comparable value of the funds extended to the borrower in the form of goods or services once the project is up and running, or provide funds as a straight loan with interest, or invest in the project in return for equal shares. Crowdfunding enthusiasts emphasize that it's not about the money. They enjoy being intimately involved with helping others pursue their dreams and feel that their small contribution packs a wallop—that it really counts in moving a project forward.

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[198] See: Cisco White Paper. 2015. Seizing Opportunity in the New Age of Financial Services. http://www.cisco.com/c/dam/en/us/products/collateral/security/financial-services.pdf

[199] Rogers, E., Carley, E., Deo, S., & Grossberg, F. (2015). *How Information and Communications Technologies Will Change the Evaluation, Measurement, and Verification of Energy Efficiency Programs.* Washington, DC: American Council for an Energy Efficient Economy (ACEEE).

Alternative currencies, often referred to as community currencies, local exchange trading systems (LETS), or micro currencies, began to take hold in locales around the world after the economic collapse of 2008. Alternative micro currencies are really social currencies that enable the collaborative exchange of goods and services to flourish in the Sharing Economy. As in other areas of the Sharing Economy, people are bypassing the middlemen, the markups, and the interest rates imposed by credit card companies, and exchanging their labor time directly with one another.

But what makes this different from old-fashioned, one-on-one bartering of services is that Web-generated apps provide individuals with a mechanism to store and use points, represented by comparable labor time, for the exchange of all kinds of goods and services, in both the social economy and market economy.

There are more than 4,000 micro currencies in circulation around the world. Many of them are based on the labor time one person gives to another in making a good, repairing an item, or performing a service. The hours are stored in a time bank, just like cash, and exchanged for other hours of goods and services.

Other community currencies traded in LETS are designed to facilitate the exchange of goods. The WIR currency in Switzerland credits sales against future purchases for its members. When a seller receives credit for an item sold, it can be spent buying another item from another WIR member.

Community currencies are also employed, in part, to prevent wealth from leaking out of the community. BerkShares, in the Berkshire region of Massachusetts, is one of a number of social currencies that is designed to encourage local buying. Members purchase BerkShares from any of the six banks in the region at the same exchange rate as the dollar, with a little extra bonus. If a member deposits $95, he or she is given $100 worth of BerkShares from the bank, making the exchange a net gain for the member. He or she then uses the shares to purchase goods and services in local business establishments, which ensures that the money continues to circulate in the local economy.

Virtual currencies like Bitcoin are also proliferating in peer-to-peer digital networks. Industry analysts expect to see the emergence of thousands of virtual currencies circulating on new digital platforms in the coming decades. Luxembourg’s financial services industry is likely to play a prominent role in establishing the new virtual currencies or managing the accompanying platforms.

Bitcoin and other virutual currencies have suddenly become viable because of the emergence of Blockchain technology. This new technology, once perceived as a threat to the very existence of the financial sector, is beginning to be embraced by financial institutions anxious to reduce fixed and marginal cost in their day-to-day business operations. Blockchain is a digital distributed ledger which allows parties to log transactions directly with one another, eliminating intermediaries and centralized clearing houses. The near zero marginal cost of blockchain transactions disrupts the conventional financial industry model, forcing the sector to adapt or perish.

The new digitally mediated funding mechanisms make possible a new generation of investment capabilities that foster a higher level of economic performance.[200] Digital financial literacy go hand-in-hand with the new digital financial platforms and require a wholesale transformation in financial education. This should be a key priority, given Luxembourg's status as one of the leading financial capitals in the world.

A Synergistic Deployment of the Integrated Proposals Holds Considerable Promise

Plugging into an Internet of Things infrastructure and creating new business models will reposition the financial sector in Luxembourg as the leader in the new digital economy. European investment on infrastructure-related projects totaled $741 billion in 2012, much of it to shore up a second industrial revolution general purpose technology platform that is outmoded, and whose productivity potential has long since been reached.[201] If just twenty five percent of these funds were redirected and earmarked in every region of the European Union to assemble an Internet of Things infrastructure, the Digital Union could be phased in between now and 2040. Clearly, Luxembourg's financial sector will play a critical role in the investment opportunities that accompany the build out and scale up of an Internet of Things smart Digital Europe.

The European Investment Bank has recently reprioritized its lending criteria for the allocation of regional development funds. In the quest to advance the Digital Europe agenda and the integration of an integrated single market, the EIB has prioritized funds focusing on the key pillars that make up the infrastructure for the Internet of Things platform. These priorities include allocation of funds for the research, development, and deployment of digital communication and Big Data, the digital Energy Internet, the digital Transportation and Logistics Internet, and the adaption of digital technologies for smart buildings. European Investment Bank funds are often leveraged with additional private funds to provide the financial resources necessary for the build out of the new digital infrastructures. Nations like Luxembourg seeking investment funds are best-served by developing road maps that transform their jurisdictions into fully digitalized economies.

[200] Willard, Rik and Michael Casey, The Agentic Group, The Blockchain Opportunity in Luxembourg (May 19, 2016).
[201] See: http://www.reuters.com/article/us-europe-infrastructure-slowdown-idUSBRE92R04H20130328

STATE OF PLAY AND LUXEMBOURG VISION

"Luxembourg: a sustainable, world-class financial hub at the vanguard of the digital revolution making transformation happens." The Finance Working Group (FWG) has had the opportunity to sketch an overarching vision of where the financial sector - and the finance framework as such - will head in 2020 and beyond. This vision strives to reflect the future desired state of the financial framework. Setting aspirations first helps to set goals and objectives designed to make the vision happen later. Key elements to make the vision happen include:

- A resilient and diversified international financial sector servicing customers in Luxembourg, Europe, and the world
- A financial center that incorporates the digital revolution successfully
- A financial center with a high capacity to adapt its offer in order to facilitate the TIR
- A world-class framework for data protection and infrastructure for e-service
- A worldwide leading hub for financial innovation, SRI and transparency where impact and socio-economic sustainability go hand-in-hand

The Financial Underpinnings of a More Productive Luxembourg Economy

If the Grand Duchy of Luxembourg is to elevate its level of economic performance to meet or exceed expectations of the Third Industrial Revolution, it will need both purposeful effort and a different pattern of investments. By purposeful effort we mean the set of new skills, smart policies and programs that enable the development and deployment of energy efficiency upgrades, renewable energy technologies and, more broadly speaking, the substantial upgrade of its existing infrastructure. The latter includes buildings, industrial operations, transportation and telecommunication services, power and water supplies, etc. By a different pattern of investment, we refer to a higher level of annual outlays in those infrastructure upgrades which move away from the current generation of Second Industrial Revolution technologies and toward Third Industrial Revolution digital technologies – the Communication Internet, the Renewable Energy Internet, and the automated Transportation and Logistics Internet atop an Internet of Things platform.

As of 2014 Luxembourg is a €49 billion economy as measured by its Gross Domestic Product, or GDP.[202] While a small nation of 563,000 inhabitants, it has one of the highest per capita GDPs in the world. Like all nations, however, it must confront the social and economic reality of both

[202] Luxembourg in Figures 2015, STATEC (Institut national de la statistique et des étude économiques), September.

climate change[203] and an economy that is less robust than in past years. The reason that climate change has become such a big problem is the hugely inefficient use of energy and other resources that results in the pumping of large quantities of greenhouse gas emissions into the atmosphere all around the globe.[204] Were both Luxembourg and the global economy twice as energy-efficient as they are today, by definition only half of the energy-related greenhouse gas emissions would be forced into the upper atmosphere. At the same time, the very reason that the climate is burdened by an excess of greenhouse gas emissions is the same reason the economy is constrained by an array of costs which robs it of its overall vitality—that is, the wholly inefficient use of energy and other resources. Hence there is the very real need to solve both the climate and the economic problems together, through much greater emphasis on the productive use of assets and resources. And here is where Luxembourg has a critical asset – its financial prowess and strength – which must be redirected toward a more productive transformation of its technologies and infrastructure.

According to the data maintained by STATEC, the Grand Duchy of Luxembourg has an estimated 3.3 Euros of capital stock for each Euro of GDP.[205] In 2014, therefore, the nation's total capital stock was estimated at about €168 billion. Building stock is about €95 billion while transport is €18.8 billion.[206] There are two elements worth noting here. First, and most interesting, Luxembourg appears to transform only 32 percent of total economic activity into GDP. This is closely related to Luxembourg being a very open economy, with exports reaching 213% of GDP and imports 178%.

[203] Perhaps as a timely reminder of the growing problem of climate change, the weather editor for the *Washington Post,* Jason Samenow writes in a 16 May 2016 news story that the average temperature of the planet was 1.11 degrees Celsius above the long-term average in April, shattering the old record from 2010 by 0.24 degrees Celsius. He notes further that "2016's average global temperature is so far out in front of any preceding year that climate scientists say there's basically no way it won't become the warmest ever recorded." See, Earth's relentless streak of record-warm months expands to seven.

[204] By way of comparison, the TIR Master Plan for Nord-Pas de Calais suggested an eventual efficiency improvement that could reduce total energy use by about one-half with renewable energy technologies meeting all remaining energy needs by 2050. This would effectively bring that region's energy-related carbon emissions down to zero. See, Nord-Pas de Calais Third Industrial Revolution Master Plan – 2013, Jeremy Rifkin, Benoit Prunel, Solenne Bastie, Francis Hinterman, John Laitner and Shawn Moorhead. Bethesda, MD: TIR Consulting Group LLC. 2013. For yet a different approach that relies more heavily on renewable energy technologies throughout the world's economies, see Jacobson, Mark and Mark Delucchi et al., 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All- Sector Energy Roadmaps for 139 Countries of the World, August 9, 2015.

[205] Luxembourg in Figures 2015, STATEC (Institut national de la statistique et des étude économiques), September.

[206] Perhaps also of interest, information and communication technologies are estimated to be about €1.6 billion. Needless to say this amount will need to grow dramatically if we are to see a fully operational and productive energy Internet, a logistics and transportation Internet, and a communications Internet that links all buildings and other elements of the Luxembourg infrastructure. That, of course, will require large-scale investments.

This compares to the United States which generates 56 percent of its output into GDP. A more productive infrastructure which builds on a greater local capacity would likely increase this ratio and provide the economy with a greater level of resilience for any number of reasons. Second, Luxembourg has a Gross Fixed Capital Formation of €9.4 billion per year.

If this is a reasonable proxy for annual investment in capital stock (or infrastructure), and if we anticipate an almost three-fold expansion of the economy by 2050, one can quickly imagine that 50 years or more may be needed to fully transition the economy from a Second Industrial Revolution mode to a Third Industrial Revolution infrastructure. Hence, the need to quickly aggregate both supply and demand, and to accelerate the redirection of capital away from the old and into the new. This brings us then to a key idea: an emerging coalescence around the establishment of a Luxembourg Sustainable Development Finance Platform (LSDFP). This proposal was first referenced by the Luxembourg Financial Working Group.[207]

The LSDFP complements the three key ideas set forth by the TIR Consulting Team: (a) the need to build up a more productive capacity in the Grand-Duchy of Luxembourg through the more efficient use of energy and other resources[208]; (b) the implementation of an adapted Sustainable Energy Finance (SEF) model to augment via bond issuers and private financial sector actors, the scale of phased-in capital that is required to transition Luxembourg into a Third Industrial Revolution economy[209]; (c) the deployment of a new set of blockchain technologies that can reinvigorate the national investment capacity to continue the steady march toward a higher level of economic performance.[210] Financial education and financial literacy have also been identified as key enablers and priorities going forward. Moreoever, both the Financial Working Group and the TIR Consulting Team have also advanced a series of complementary financial strategies that can further build out the contribution of the financial community.

In the discussion that follows, these key elements are presented as a series of five complementary proposals that might accelerate the economic performation of Luxembourg. Proposal 1 focuses on the Luxembourg Sustainable Development Finance Platform as envisioned by the Working Group on Finance, accompanied by the Sustainable Energy Finance model. Proposal 2 describes the potential development and deployment of the Blockchain

[207] See generally, TIR – Pillar "Finance" – Document de restitution (2 May 2016).

[208] Laitner, John A. "Skip", Exploring the Economic Benefits of the TIR Innovation Scenarios (19 May 2016); see also Robert Wilhite Kathleen Gaffney, and Tiffany Chow, Navigant Consulting, Inc., The Third Industrial Revolution for Energy - Grand Duchy of Luxembourg (19 May 2016).

[209] Byrne, John and Job Taminiau, Foundation for Renewable Energy and Environment (FREE), Assessment and Application of Sustainable Energy Financing as Infrastructure Investment in Luxembourg: A "Sustainable Energy Finance" (SEF) Strategy (19 May 2016).

[210] Willard, Rik and Michael Casey, The Agentic Group, The Blockchain Opportunity in Luxembourg (May 19, 2016).

technology. Proposal 3 suggests immediate opportunities beyond Luxembourg itself. Proposal 4 provides an overview of a number of supplemental financial strategies. Finally, Proposal 5 describes the mobilization of a larger strategic effort to ensure success within the financial arena.

PROPOSALS

Proposal 1: A Sustainable Development Finance Strategy

1.1 The Luxembourg Sustainable Development Finance Platform

The key project and recommendation in this section regarding the Financial sector as an enabler consists in the creation of a central interface platform that would support the financing of investable projects in all the pillar sectors of sustainability (economic, social, environmental), including TIR projects (but not limited to), as well as their promotion among potential investors and project promoters.

This platform could be called the “Luxembourg Sustainable Development Finance Platform” (LSDFP). The main idea is to have the “LSDFP” as a body to interface between potential financial contributors (public and private) and project promoters (public and private) and to assess each of the projects submitted in order to ensure compliance with a given set of eligibility criteria as well as quality checks on the feasibility of the project, the value creation and the output of it to potential investors.

Most TIR projects, if not all of them, will require some sort of financing and investment. It is therefore important to connect projects (of all sizes) to all types of potential investors via different investment channels (see chart here attached).

This platform can provide potential investors and project promoters with various advantages:

- Provide access to privileged information and opportunities.
- Allow financial contributors to invest according to their individual risk appetite and expectations in terms of financial return and impact, including in kind.
- Allow project promoters to submit project proposals in line with their policies, missions, mandates or business plans.
- Allow structured and blended financing (public/private) for better risk management (i.e. through guaranties) and increased leverage.
- Provide quality and compliance certification.

The platform can be set up under the form of a PPP (private-public-partnership, see description below). Project promoters will need guidance to choose the right financing instruments. The eligibility of project proposals to the platform should be based on a preliminary assessment.

A wide range of stakeholders will collaborate on the LSDFP. Besides investors and project owners:

- Government (national and local)
- Relevant "*Etablissements publics"* (public law bodies)
- Professionals and financial institutions/associations (ALFI, ABBL, ACA, Insurance Companies…); Intermediate Financial Advisors
- Asset managers
- Audit firms
- Luxembourg Stock Exchange LuxFlag[211]
- UNPRI expert in Luxembourg[212]
- Interested private sector companies PPPs
- Civil Society Organizations, NGOs

The implementation of this project will help to bridge a gap that still exists between mutually reinforcing types of (public and private) financial contributors and investors in search of investment opportunities in the field of sustainable development, including the TIR, on the one side, and project promoters in search of adapted financing for the implementation of their projects, on the other side.

The results to be expected in the economic, social and environmental fields will include:

- Increased economic and financial activity;
- Improved infrastructure (physical and digital) throughout the three constitutive pillars of sustainable development: economic, social and environmental;
- Enabling the pillar sectors and transversal axes of the TIR;
- Leverage on private sector investment through smart use of public seed funding and funding for risk mitigation and technical assistance;
- Increased effectiveness and mutual reinforcement, in facing the complex challenges of sustainable development, through a multidisciplinary and multi-stakeholder approach;
- Credible contribution to the global public good of sustainable development and the implementation of Luxembourg's national commitments taken under the universal agendas of the Sustainable Development Goals (Agenda 2030) and the fight against climate change (COP21 Paris Agreement);
- Better access to education and health care, including in the form of an in natura return;

[211] The LUXEMBOURG FUND LABELLING AGENCY (LuxFLAG) is an independent, nonprofit making, association created in Luxembourg in July 2006 by seven founding partners who are the Charter Members. The agency aims to promote the raising of capital for Responsible Investment sector by awarding a recognisable label to investment funds. Its objective is to reassure investors that the applicant investment fund invests, directly or indirectly, in the responsible investment sector. The applicant fund may be domiciled in any jurisdiction that is subject to a level of national supervision equivalent to that available in European Union countries. See: http://www.luxflag.org/.

[212] See: https://www.unpri.org/about.

- Increased number of climate / environment related projects;
- Job creation.

We may nevertheless need to ensure that the investor can also decide which type of project and impact they want to invest in. Therefore, the financial solution should be based on two possibilities: either a financial pool from which the project can be financed; or, on the other hand, through specific capital calls to further investor commitment.

In terms of resources, we can distinguish between financial resources and non-financial ones:

- Financial resources (both domestic and international):
    - Public seed funding and funding for mitigating the risk of private sector investors and for technical assistance at the project level;
    - Private investment;
    - European Funds (e.g. Juncker Plan – Investment Plan for Europe).
- Non-financial resources:
    - Increased capacity for--
        - defining eligibility criteria,
        - project sourcing,
        - project design ad formulation,
        - project assessment (based on UNPRI principles?),
        - financing needs assessment,
        - outreach to financial contributors and project promoters,
        - quality control, including through a labelling system, defining and executing a communication plan,
        - administrative tasks.
- Legal framework for crowdfunding and leasing

Figure 1 that follows provides a conceptual overview of how the LSDFP might function, and encourage a greater collaboration and coordination among key entities within the financial markets of Luxembourg. At the same time, an information box highlights several of the key characteristics of the LSDFP.

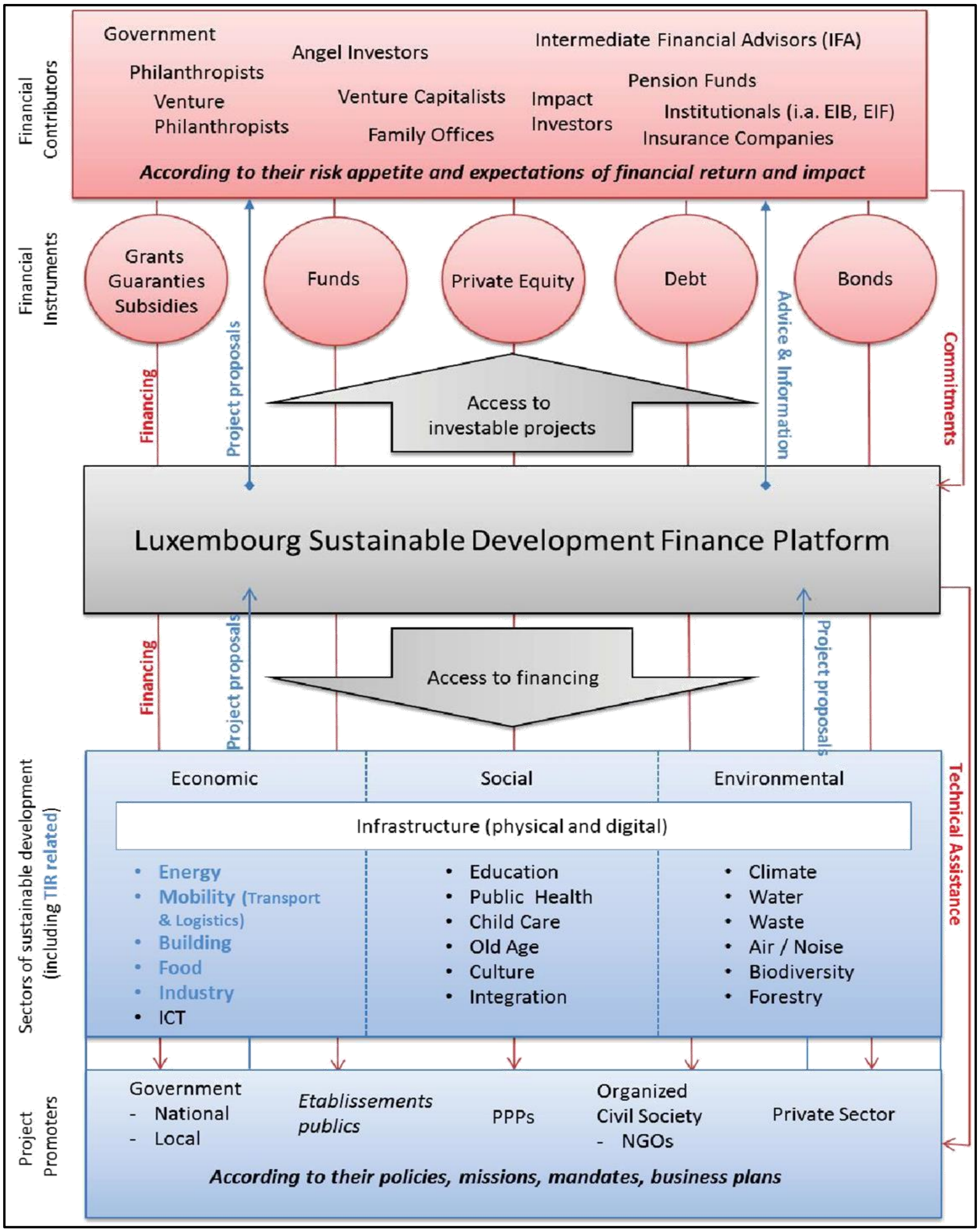

Figure 1. Overview of the proposed functioning of the LSDFP.

Information Box: The Luxembourg Sustainable Development Finance Platform – Key Characteristics

Preliminary remark on the legal form of the LSDFP:

A proper analysis on the optimal legal structure for the platform needs to be carried out. Regardless of the legal form, the LSDFP is to be established in the spirit of a Public Private Partnership (PPP). Availabe legal forms include the "classic" non-for-profit organization forms of asbl ("association sans but lucratif") or Foundation.

The new legal form of "société d'impact societal" (SIS; legislation pending) may also be considered for the establishment of the LSDFP. However, in deciding the legal form of the LSDFP, at least two (to some extent contradictory) aspects must be taken into consideration:

- The status of SIS will probably to be bestowed through ministerial accreditation on commercial companies (S.A., Sàrl, Sociétés en commandite...) and not on not-for-profit organisations (i.e. asbl).
- The SIS may very well be the status that best embodies the spirit of a PPP underlying the concept of the match-making platform between project promoters and investors, both from the public and the private sector.

Main characteritics of LSDFP:

- LSDFP serves a public mission, i.e. providing sustainable financing for sustainable development.
- The objective of this public mission justifies public seed funding for financial risk mitigation and technical assistance.
- The implementation of the public mission requires financial and non-financial input from private sector actors.
- A commercial perspective motivates long term engagement of private sector actors.
  Private sector actors respect the spirit of the initial public mission.

LSDFP is established and works as an interface between financial contributors in search of investable projects, on the one hand, and promoters of investable projects, on the other hand. It provides financial contributors access to investable projects in the economic, social and environmental sectors relevant to sustainable development.

LSDFP launches calls for project proposals in the sectors of sustainable development, including TIR related project proposals. It provides project promoters access to financial contributors and adapted financial instruments.

LSDFF proactively reaches out to potential financial contributors and compiles investment proposals and adapted investment instruments and makes them available to project promoters.

Luxembourg Sustainable Development Finance Platform (LSDFP) further details on:

- **People (Stakeholders)**
  - LSDFP is established and works as an interface between:
    - International and domestic financial contributors/investors (public, private, institutional) and Intermediate Financial Advisors (IFA) in search of investable projects, and
    - Promoters of investable projects, including in TIR related sectors.

- **Process (Functions)**
  - LSDFP provides technical assistance to the promoters in the preparation phase of their respective project. LSDFP analyses the demand for financing of investable projects and the offer/availability of financing from public, private, institutional and blended sources.
  - LSDFP advises and provides investors and IFA information on and access to investable projects in the economic, social and environmental sectors relevant to sustainable development, including/primarily the TIR related sectors:
    - LSDFP launches calls for project proposals in the sectors of sustainable development, including the TIR related sectors.
    - LSDFP assesses the eligibility of project proposals and rates the project against criteria such as the Sustainable Development Goals (SDG), their targets and indicators (as approved by the United Nations) as well as the GRI criteria and definitions, respectively their relevance in relation to the TIR. The indicators, flowing from the Sustainable Development Goals and their related targets, according to which the eligibility of sector projects for financing on the basis of the match-making efforts of the LSDFP is to be assessed, should reach a level of granularity taking into account relevant national specificities. As to their eligibility, the submitted projects may be ranked according to the number of SDGs they credibly intend to serve. They must not produce any counterproductive effects in relation to the other SDGs, and – in order to foster the social and human character of projects – they should allow for in-kind investment (i.e. skill sets) and return, as much as for financial investment and return.
  - LSDFP advises and provides project promoters access to potential investors and IFA and financial instruments adapted to their project activities.
    - LSDFP proactively reaches out to potential investors and IFA and compiles financial commitments and adapted financial instruments and makes them available to project promoters.
    - LSDFP proposes financing options to project promoters that are adapted to the financing needs of their project activities.
  - LSDFP provides a book-keeping function of more or less precisely earmarked financial commitments and actual financial flows towards and from investable projects.
- **Technology**
  - LSDFP organises an online marketplace where investors/IFA and project promoters can meet.
  - LSDFP manages a database collecting information about:
    - IFA and their financial instruments
    - Project promoters and their investable projects.
  - LSDFP capitalises on pre-existing market infrastructure and capacity (i.e. Angel-List, European Investment Project Portal (EIPP) and Fundsquare) and explores the need for tailor-made algorithms.

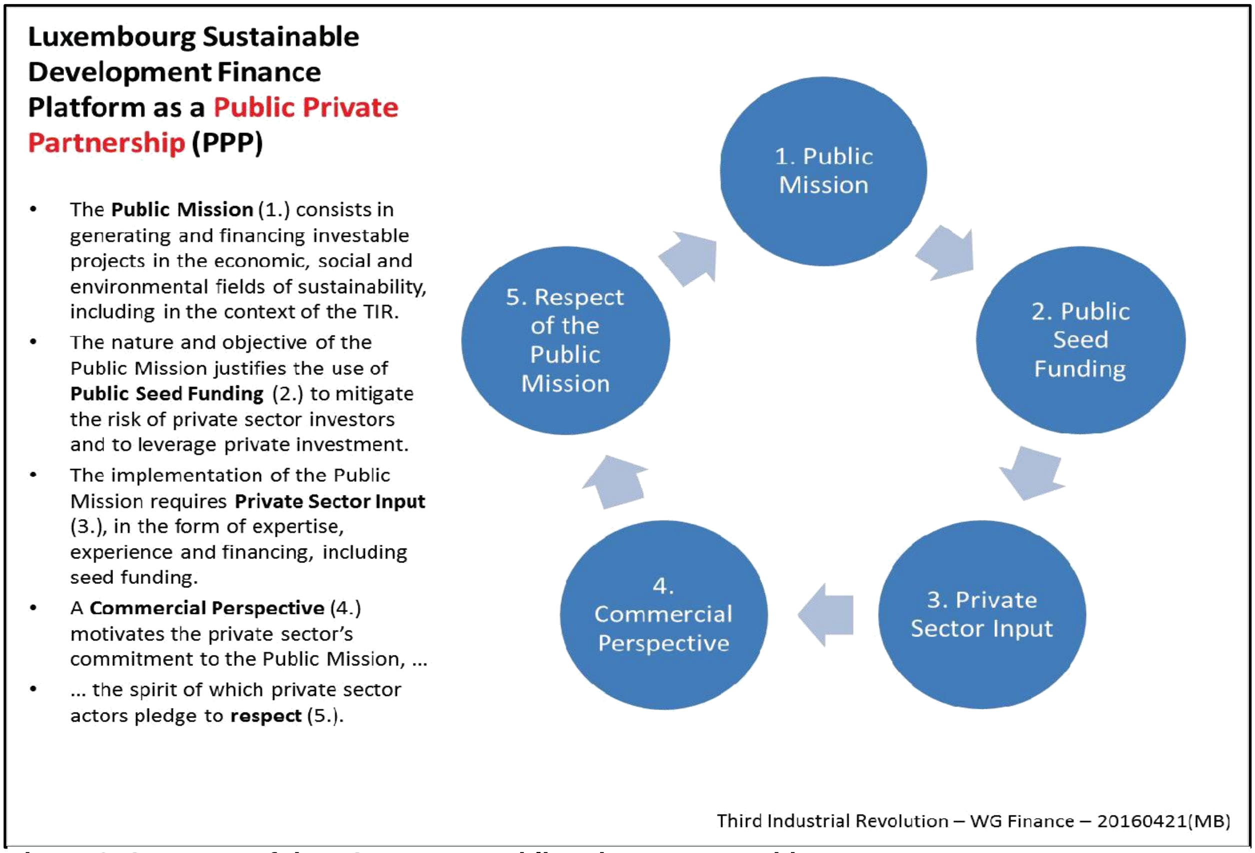

Figure 2. Structure of the LSDFP as a public private partnership.

Some concluding thoughts and suggestions for the LSDFP:

- The establishment of an LSDFP should not be perceived or interpreted as an attempt of the public sector to bail out of their existing (i.e. financial) obligations and commitments, regardless of the sector activities that, in the future, may receive financing through the match-making efforts of the LSDFP. On the contrary, the activities of an LSDFP should leverage like-minded private investment in addition to existing funding through the state budget.

- The governance structure of the platform (multistakeholder representation), its IT infrastructure (adapted to the needs in terms of volume and reliability) and the necessary skill sets (pluri-disciplinary) for its staff have to be carefully assessed.

- As to the options to cover the operational cost of the LSDFP, the idea of a membership fee for investors and a handling fee per project could be addressed.

1.2 The Luxembourg Sustainable Energy Finance Program (LuxSEF)

As indicated in in the overview discussion, a critical financial mechanism that would underpin the interaction between supply and demand for sustainable energy resources at infrastructure-scale is called LuxSEF. LuxSEF operates in parallel to the LSDFP, in particular connecting with participants who have been informed and motivated by LSDFP, and who, in turn, can design and implement cost-effective energy efficiency and renewable energy investment projects. It enables infrastructure-scale change through structured and standardized arrangements between capital providers, ESCOs, and program participants (public and private). Such a model is necessary when one considers the significant self-funding potential that is available within Luxembourg. By way of example, we can illustrate the potential scale of a Phase I investment scenario to upgrade the Luxembourg building stock to a higher level of energy performance. Table 1 summarizes an assessment of the self-funding investment potential of buildings which might be upgraded in the Grand Duchy. The investment magnitudes, at full potential, cover both rooftop solar energy and energy efficiency upgrades, amounting to €5.8 billion over the next ten years or so. Of this €5.8 billion, the energy efficiency investment potential is €3.2 billion while rooftop solar photovoltaics (PV) represent €2.6 billion. Further details underpinning the magnitude of potential investmensts are provided in subsequent discussions that follow.[213]

Table 1. Overview of key economic, environmental, and social contributions resulting from a combined deployment of rooftop solar PV and energy efficiency in the built environment. Euro amounts in millions.

Dimension	**Energy Productivity**		**Solar PV**		**Total**	
	Phase 1	Full Project	Phase 1	Full Project	Phase 1	Full Project
Investment Potential (millions)	€665	€3.200	€532	€2.600	€1.200	€5.800

[213] The working estimate of investment potential given here is not intended as a firm recommendation of what Luxembourg might choose to develop; rather, it only highlights the potential scale of the opportunity

Financed term (years)	12		20		NA	
Cost per kWh (cents/kWh)	8		15		NA	
Direct jobs per year (over the next decade)	800 – 1.000	4.000 – 5.000	500 – 1.000	2.600 – 5.000	1.300 – 2.000	6.600 – 10.000

The Luxembourg Sustainable Energy Finance Program (LuxSEF) is proposed as a main building block which uses low-cost finance that is paid for directly through large-scale energy bill savings. This can unlock transformative, infrastructure-scale level investment and change. In short, LuxSEF supports the work of LSDFP as it:

- Packages Luxembourg community's need for a more productive and sustainable economy into **actionable and financeable portfolios** that can attract low-cost capital, and do so at a scale and rate of return that is attractive to investors;
- Relies on **standardized transactions** on a common, standardized documents platform that accelerates supply and demand of sustainable energy finance and keeps transaction costs low;
- **Guarantees energy and Euro savings** for investors and program participants alike that match or exceed all financing and capital costs; and
- **Enables the market** and stakeholders, including Energy Service Companies (ESCOs), civil society organizations, investors, relevant public law bodies, and intermediate financial advisors, to collaborate in scaling up a Third Industrial Revolution transition.

To do so, the mechanism needs to be:

- **Self-financing:** SEF economics do not require regulated price increases to cover renovation costs nor rely on taxes to capitalize renovation.
- **Market-tested:** The SEF strategy draws from a $72.5 million market-tested application that was rated AA+ by Standard & Poor's rating service. Other programs have since been implemented in California, Washington DC, and Pennsylvania.
- **Capable of unlocking a suite of technologies:** The mechanism can be applied to a wide range of different technologies.
- **Flexible:** Different jurisdictions present different legal, policy and other conditions that require the financial mechanism to be adaptable to local circumstances.
- **Capable of offering a broad range of benefits.**

1.2.1 SEF Characteristics Relevant to Luxembourg

At its core, the SEF model is anchored by an economic perspective that builds on a basic principle of energy efficiency, or energy productivity, as it is made specific to Luxembourg--that is, monetizing an array of savings which cost less than paying the retail price for energy, water and materials as the source of its capital investments. For example, a recent study of the institutional building stock in Luxembourg found retrofit costs of 0.04 to 0.08 €/ kWh for the majority of floor area in their sample. [214] The 2014 cost of electricity was 0.166 and 0.075 €/kWh for households and industry, respectively. The cost to save energy, therefore, is considerably below the cost to use that energy.

The gap between the cost to buy energy and the cost to save energy forms the basis for capital investment. In other words, the direct savings (or the use of renewable energy to lower the use of more expensive energy resources) are used to pay back initial investments that enable the reductions. Critically, SEF economics avoid the practice of many governmental and regulatory programs currently in use which assess end users for funds that conventional utilities operate to meet sustainability goals. As such, SEF economics do not require regulated utility price increases to cover renovation costs. SEF economics similarly does not rely on taxes to capitalize renovation but reaps social advantages such as benefiting low-income households.[215]

Capital investments are used to procure energy, water, and material conservation measures and on-site renewable energy options to lower participants' costs. Figure 3 offers a conceptual overview of the SEF arrangement: capital investments are attracted to implement energy efficiency measures and renewable energy options **up to the maximum point of savings** that can be covered without raising the original energy costs of the participant. After debt service payments have fully paid back the capital investments, over a period of 10-14 years, all remaining savings accrue to the participant of the program over the next 6-10 years or so (with the assumption of a typical project life of 20 years).

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[214] Hoos, T., Merzkirch, A., Maas, S., Scholzen, F. (2016). Energy consumption of non-retrofitted institutional building stock in Luxembourg and the potential for a cost-efficient retrofit. Energy and Buildings (published online 01 April, 2016 at http://www.sciencedirect.com/science/article/pii/S0378778816302213). Doi: 10.1016/j.enbuild.2016.03.065

[215] The approach is compatible with the 'State Renovation Fund' described in the Working Group 'Building' Final Outcome Document (Version 02.05.2016). This proposal is detailed on page 19 of the Third Industrial Revolution Working Group 'Building' Final Outcome Document (Version 02.05.2016).

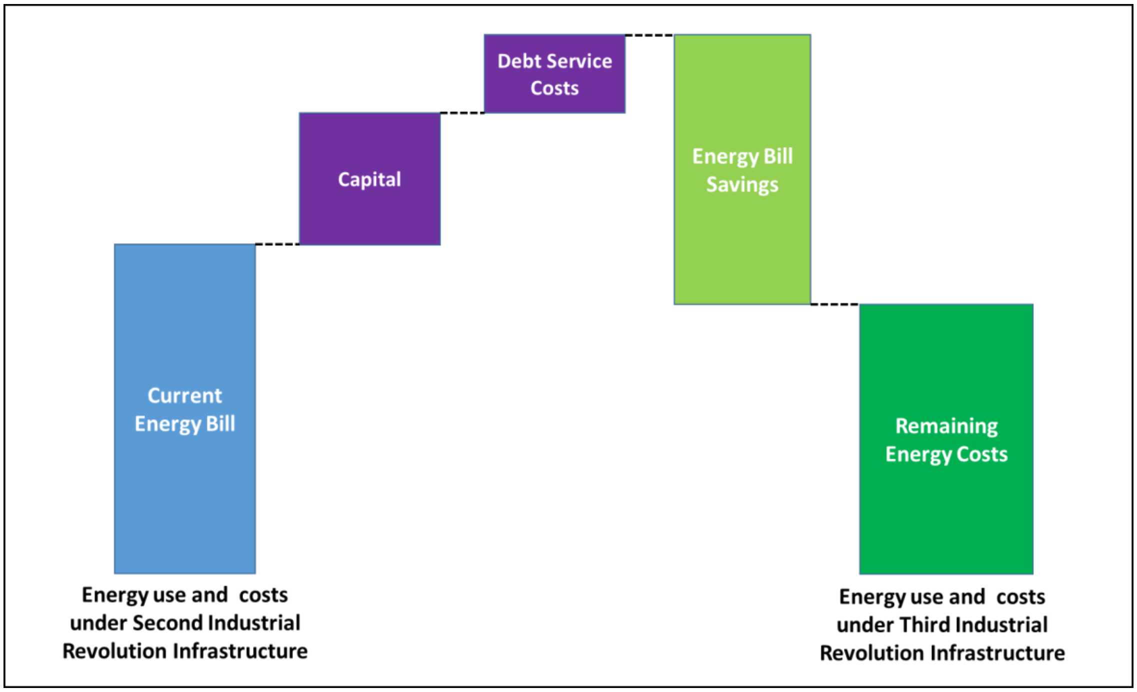

Figure 3. Conceptual overview of reduction of energy use and costs for program participants under SEF programming.

1.2.1.1 SEF: A Market-Tested Model

The SEF investment model was first applied in the United States. Operationalized through the Delaware Sustainable Energy Utility (SEU)[216] in the U.S. state of Delaware, on behalf of six state agencies and two institutions of higher learning, the Sustainable Energy Bond Series was issued in 2011. The state-wide, tax-exempt bond issue raised $72.5 million in sustainable energy capital from the private market, sufficient to invest in energy saving measures that deliver a guaranteed $148 million in aggregate energy savings.[217] All-in program costs, including

[216] The SEU concept is the result of 20 years of research conducted by Dr. John Byrne and his colleagues at the Center for Energy & Environmental Policy (CEEP) at the University of Delaware. Additional information on the model can be found at http://freefutures.org/seu-initiative/.

[217] Original planned issuance of the bonds stood at $67.4 million. However, average coverage of orders and allotments by maturity of the DE SEU bond offering was 1.2x. In addition, the $67.4 million par value Sustainable Energy Bond was oversold within two hours of its offering. The serial bond issue generated premiums in excess of $5 million and sold at the low arbitrage yield of 3.67% over its 20 year debt service period.

capitalized interest over the serialized maturity of the financing, were $110 million thus generating a $38 million premium benefit for the program participants.[218]

First year **savings of the program are 3% above the guaranteed cost savings of 25%.** [219] Annual energy savings for the Delaware SEU projects delivers an annual emission reduction of 46.8 million pounds of carbon dioxide (CO_2). Additionally, research contrasting the Delaware SEU with conventional energy utilities in the United States finds considerable SEU outperformance in terms of realizing energy savings.[220] The serialized maturity schedule of the DE SEU bond offering provides the opportunity of combining short-term and long-term retrofits: the average simple payback of the bond offering is 14 years with maturities as long as 20 years. Serialization additionally enables cash flow optimization resulting in lower overall interest rates: The maturity schedule includes 1-year bond maturities at 0.65% borrowing rate all the way up to 20-year maturities (rate = 4.37%) for a 3.67% effective borrowing rate. Noting the strong general credit quality of the State of Delaware, the contractual guarantee provisions which include an absolute and unconditional payment provision upon annual appropriation, [221] and annual payments that are date certain and not subject to acceptance, Standard & Poor's rated the sustainable energy bond at AA+.

[218] The Delaware SEU example offers a guide to how the Sustainable Energy Finance (SEF) model can unlock significant energy savings when applied in a comprehensive strategy: a national application of the model in the U.S. along the same lines as described in this chapter would present a $25 billion energy investment market in the public sector alone (i.e. applying the model in municipalities, universities, schools, and hospitals). When applied at this level, approximately 300,000 additional green jobs and 225 million metric tons of greenhouse gas emission reduction could be realized.

[219] Chu, C., Bruner, A., Byrne, J. (2015). DESEU energy efficiency revenue bond series 2011: Project savings analysis. Newark, DE: Center for Energy and Environmental Policy. Report prepared for the Delaware Sustainable Energy Utility.

[220] Byrne, J., Taminiau, J. (2016). A review of sustainable energy utility and energy service utility concepts and applications: realizing ecological and social sustainability with a community utility. Wiley Interdisciplinary Reviews: Energy and Environment, 5: 136-154. Doi: 10.1002/wene.171.

[221] Please note that "absolute and unconditional" is not the same as a general obligation: "[…] neither the state nor any political subdivision thereof shall be obligated to make payments on the bonds. Neither the faith and credit nor the taxing power of the state or of any political subdivision thereof is pledged to the payment of the principal or of the interest on bonds. The issuance of the bonds shall not directly or indirectly or contingently obligate the state or any political subdivision thereof to levy or to pledge any form of taxation whatever therefor, or to make any appropriation for their payment." (see citi post pricing commentary: Citi Post Pricing Commentary on the Delaware Sustainable Energy Utility. Of course, the U.S. case is meant to illustrate feasibility and not to be treated as a blueprint. Any investment at scale must reflect and adapt to its context.).

1.2.1.2 LuxSEF: Unlocking Sustainable Energy Technology Portfolios

The LuxSEF option can be applied to a broad range of different technologies. Figure 4 shows that the LuxSEF option could target, for instance, energy efficiency (in all sectors), sustainable mobility, energy storage, renewable energy, and distributed generation. To illustrate, an initial assessment of LuxSEF application to Luxembourg's rooftop solar and energy efficiency potential was performed. This section briefly details how LuxSEF unlocks the investment potential of these two technology options.

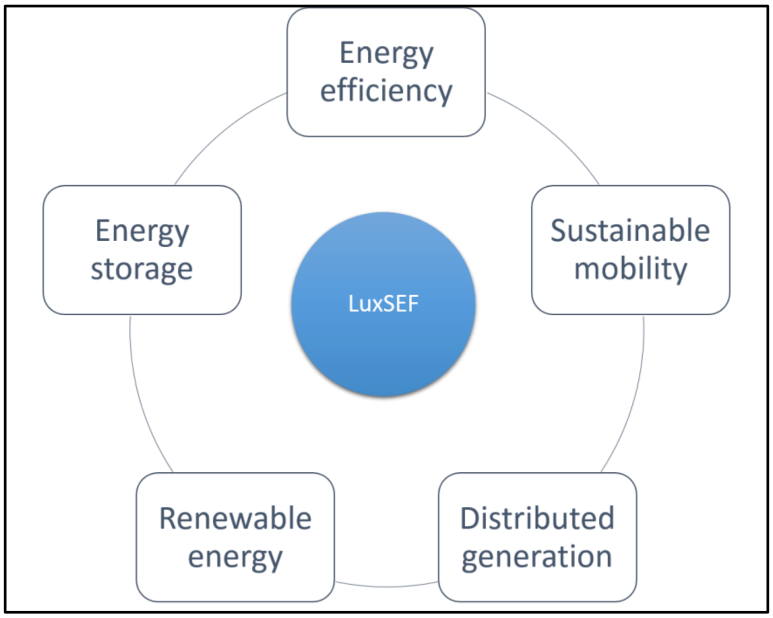

Figure 4. Overview of the LuxSEF strategy in relation to a range of technology options.

Energy Efficiency Potential in Luxembourg's Building Stock

The Third National Energy Efficiency Action Plan (NEEAP) highlights the importance and the opportunity of retrofitting the building stock in the Grand Duchy. Using STATEC data, the usable floor space per residential building type can be calculated by year of construction.[222] The residential building stock captured in the STATEC data represents about 27.4 million m^2. Of this, 18.7 million m^2 can be classified as single family home and 8.7 million m^2 as multi-family home (includes both apartment blocks and semi-residential buildings). Regarding the commercial building stock, data limitations are discussed in both the Third NEEAP and the TIR WG 'Building' Final Outcome Document. Data availability is limited to the non-residential

[222] Peltier, F. (2015). Regards (06) – sur le stock des bâtiment et logement. STATEC – institut national de la statistique et des études économiques. Link to source material: http://www.statistiques.public.lu/catalogue-publications/regards/2015/PDF-06-2015.pdf

building stock constructed since 1970 for six building types. The total usable non-residential floor space amounts to 8.3 million m^2. In addition, public building stock data is, according to the Third NEEAP, not available at all. As such, an estimated combined building stock of approximately 36 million m^2 is available in the residential and non-residential market segments.

Estimating Luxembourg's Rooftop Solar Energy Potential

A recent study from Fraunhofer Institute calculated Luxembourg renewable energy potential.[223] Updating the findings from a 2007 study that estimated renewable energy potential, [224] Fraunhofer estimates that Luxembourg has a theoretical potential to generate 33.000 GWh/a from solar PV. [225] In terms of technical potential, and specifically focusing on rooftop deployment of solar PV (as opposed to PV on land or on building facades), the 2007 study maintains that 127.000 buildings with an average 168 m^2 yields about 21.3 million m^2 of rooftops. Considering that not all rooftops are suitable for PV deployment, the 2007 study uses a 0.6 discount factor to produce a total rooftop space in the country of 12.8 million m^2.[226] Under the irradiation conditions and 15% efficiency, this translates to 2.004 GWh/a. Using updated numbers – specifically an increase of the building stock from 127.000 buildings to an estimated 160.000 buildings – the 2014 study increases the estimate to 2.524 GWh/a.[227] At an average rooftop space of 168 m^2, that translates to a total rooftop space of 26.88 million m^2 and, at a 0.6 discount factor, about 16.3 million m^2 of rooftops that are available for solar PV installation.

LuxSEF and Self-Financed Energy Productivity

Strategically, a phased plan for Luxembourg could be developed that pursues energy use reductions in the high-consumption building stock first (typically the older, non-retrofitted

[223] Schon, M., & Reitze, F. (2015). Wissenschaftliche berating zu fragen der energiestrategie Luxemburg smit besonderem fokus auf erneuerbare energien – aktualisierung der potentzialanalyse fur erneuerbare energien. Fraunhofer Institut fur System- un Innovationsforschung (Fh-ISI) and IREES GmbH.

[224] Biermayr, P., Cremer, C., Faber, T., Kranzl, L, Ragwitz, M., Resch, G., Toro, F. (2007). Bestimmung der potenziale und ausarbeiting von strategien zur verstarkten nutzung von erneuerbaren energien in Luxemburg. Fraunhofer Institut fur System- und Innovationforschung (Fh-ISI), Energy Economics Group (EEG), and BSR-Sustainability.

[225] Using 1.043 kWh/m^2 solar irradiation, 212 km^2 of available land, and an assumed 15% PV module efficiency.

[226] The 2007 study reserves half of the 12.8 million square meters for solar thermal technology installations for further calculations. Here, we calculate the technical potential of solar PV and neglect solar thermal technology and, therefore, use the full 12.8 million square meters in the calculation.

[227] Schon, M., & Reitze, F. (2015). Wissenschaftliche berating zu fragen der energiestrategie Luxemburg smit besonderem fokus auf erneuerbare energien – aktualisierung der potentzialanalyse fur erneuerbare energien. Fraunhofer Institut fur System- un Innovationsforschung (Fh-ISI) and IREES GmbH.

buildings in the residential and non-residential building stock).[228] Retrofit construction cycles for deep retrofit efforts can be estimated to take up to two years. A phased plan could therefore be to deploy retrofit rounds in two-year increments that each cover 20% of the high-consumption building stock for a total ten-year strategy.

Energy use conditions in high-consumption building stock can be lowered from the current 190, 160, and 180 kWh/m^{2}a for single family homes, multi-family homes, and non-residential buildings, respectively to 120 kWh/m^{2}a. Indeed, 120 kWh/m^{2}a can be considered a conservative value for retrofitted buildings that have benefitted from short- and long-term energy conservation measures.[229]

Energy use conditions in high-consumption building stock can be lowered from the current 190, 160, and 180 kWh/m^{2}a for single family homes, multi-family homes, and non-residential buildings, respectively to 90 kWh/m^{2}a. Indeed, 90 kWh/m^{2}a can be considered a conservative value for retrofitted buildings that have benefitted from short- and long-term energy conservation measures. Such an approach lowers energy consumption of the high-consumption stock by approximately 50% which would decrease total built environment energy consumption by 1.67 billion kWh/a or about 27.5%. This is consistent with case study analysis of deep retrofit performance.[230] The investment potential of such a ten-year deployment corresponds to about €3.2 billion. In terms of a first phase, where 20% of the high-consumption building stock is retrofitted to the same level of 90 kWh/m^{2}a, built environment energy consumption would be lowered by 5.5% or about 335 million kWh/a. Such a deployment represents a self-funding investment of about €665 million.

The contribution to electricity end-use reduction is illustrated in Figure 5 for both a Phase 1 and a Full Project deployment.

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[228] Buildings with 'normal' consumption patterns and even 'low' consumption profiles will likely also be available for retrofitting at lower cost per square meter

[229] For instance, Hoos et al. maintain that buildings can be retrofitted to at least 90-100 kWh/m^{2}a and Merzkirch et al. (Merzkirch, A., Maas, S., Scholzen, F., Waldmann, D. (2014). Wie genau sind unsere energiepasse? Vergleich zwischen berechneter und gemessener endenergie in 230 wohngebauden in Luxemburg. Bauphysik, 36: 40-43. Doi: 10.1002/bapi.201410007) similarly show that newer buildings have considerably lower energy use.

[230] Rocky Mountain Institute (RMI) (2015). Deep energy retrofits using energy savings performance contracts: success stories. Rocky Mountain Institute, Boulder, CO.

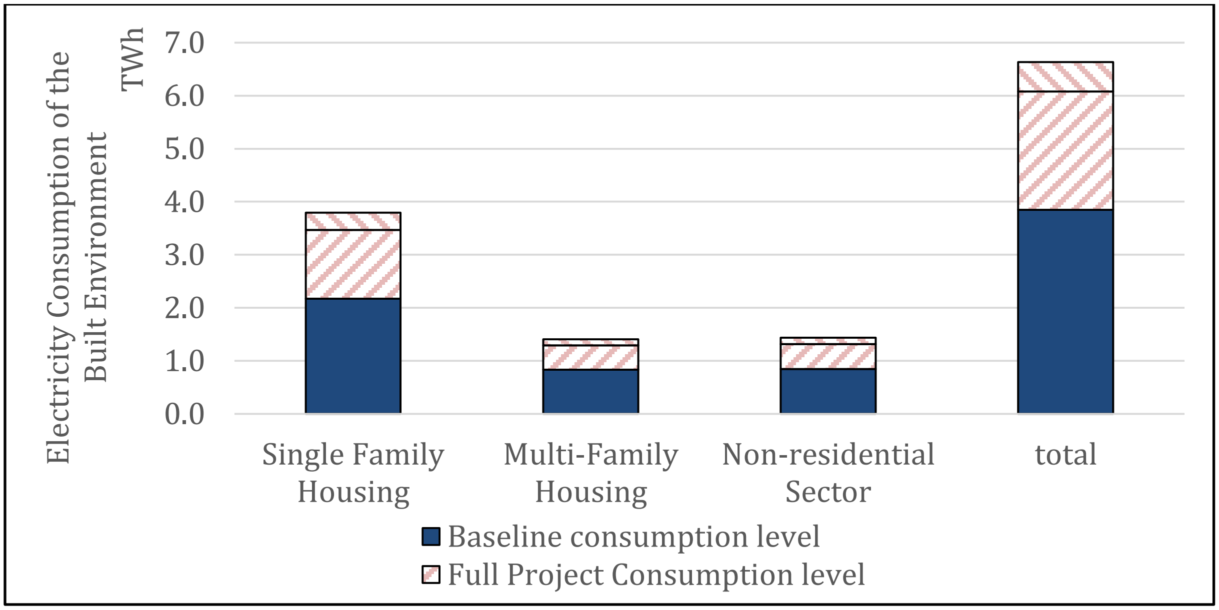

Figure 5. **Contribution to electricity end-use reduction for the three segments of the built environment (single family housing, multi-family housing, and the non-residential sector.**

LuxSEF and a "Solar Luxembourg"

A phased plan for a "Solar Luxembourg" could similarly be deployed in a ten-year timeframe with five increments of 20%. Full Project potential, Phase 1 potential, and generation level can be calculated. To allow for comparison, earlier obtained results for Amsterdam and Munich are given as well.[231] Using the solar city assessment framework developed by FREE[232], many of the assumptions held by Fraunhofer were used, with the exception of:

- Unlike the two Fraunhofer studies, which both used 15% efficient PV modules in their calculation, we used 20% efficiency levels here. 20% efficiency is in line with current state-of-the-art in the market and a large-scale deployment as envisaged under a PV bond offering within a SEF strategy should be able to negotiate high quality PV panels.[233]
- The framework reduces the Full Project potential estimate as it additionally takes into account panel-to-panel shading effects and tilt angles of the PV modules.

The estimated Full Project potential stands at 1.38 GWp. It is clear that a significant potential exists within Luxembourg a solar PV deployment would yield approximately 1.35 TWh of

[231] See Byrne et al. (2016).
[232] See Byrne et al. (2015)
[233] See Byrne et al. (2016)

electricity or roughly 28% of the country's annual electricity consumption.[234] At a €2.0/Wp system price,[235] such a Full Project deployment represents a €2.6 billion investment. At a 2013 installation level of about 100 MW, a Full Project deployment would increase Luxembourg's solar capacity dramatically. A Phase 1 solar PV component – the first 20% increment of a ten-year deployment strategy – corresponds to 0.28 GWp of solar PV which would generate 0.27 TWh of electricity annually. In terms of investment potential, a Phase 1 component represents a €413 million investment and about a 6% contribution to the country's current annual electricity consumption.

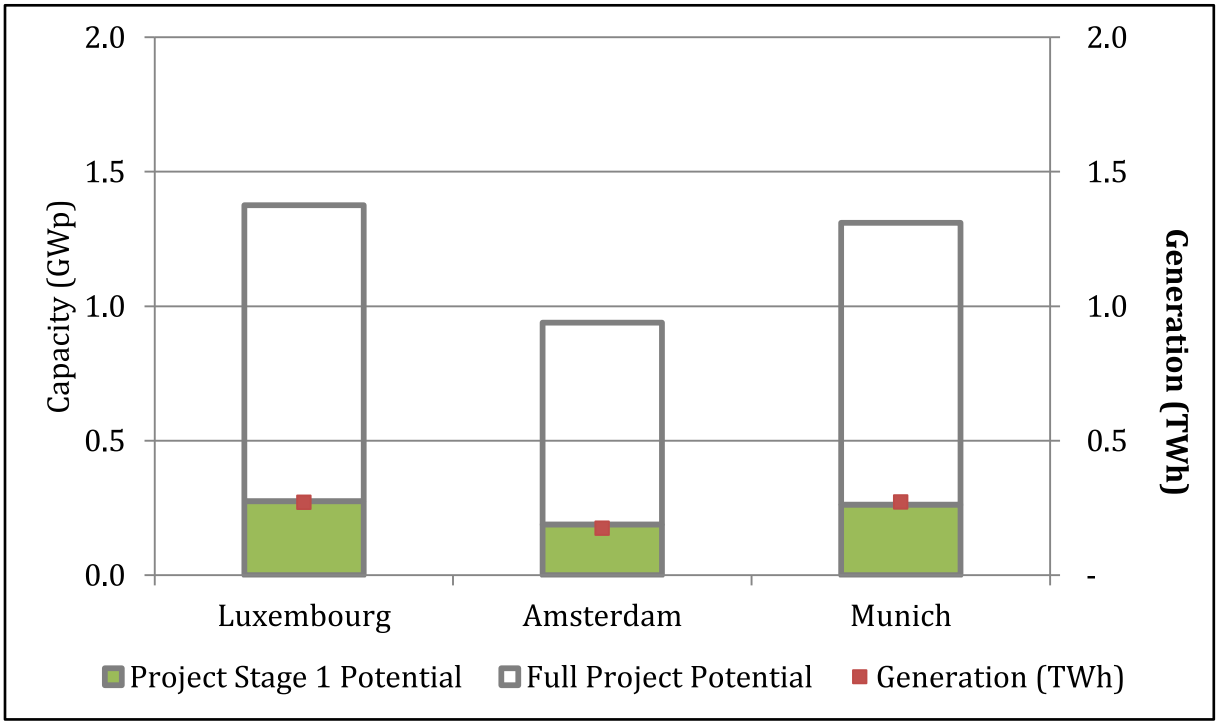

Figure 6. **Findings from the FREE assessment module for Luxembourg, Amsterdam, and Munich. The figure depicts the results when solar PV panels are installed at a 25-degree angle. Actual installation angles depend on building morphology and weather conditions.**

[234] Creos (2014). Annual Report 2014.
[235] EuPD Preismonitor (2013). EuPD Photovoltaik Preismonitor Deutschland. Ergebnisse 1. Quartal. Document can be accessed at: https://www.solarwirtschaft.de/preisindex. System price used here is the average system price for rooftop systems of 10-100 kWp. Naturally, an application as envisioned here will deploy many systems of different sizes but, on the other hand, should be able to a) negotiate favorable pricing due to economies of scale and b) benefit from technology development as deployment will take time.

1.2.1.3 A Flexible Investment Model that can be replicated to fit Luxembourg's Context-Specific Requirements

The SEF investment model has received endorsements from the White House [236] and the Asian Development Bank. [237] The SEF investment model was further recently highlighted by the International Energy Agency (IEA) as being a model capable of driving urban energy transformation. In terms of its application to other contexts, the SEF investment model and the SEU authority model have diffused across the United States and globally.[238] SEF models are now active in Washington, D.C., Pennsylvania, and California. Seoul Metropolitan Government is actively considering implementation of the application.

An example of SEF diffusion and context-specific application is the Pennsylvania Sustainable Energy Finance Program (PennSEF, operated by FREE and partners).[239] PennSEF provides technical and legal assistance, as well as low-cost capital, for energy improvement projects by municipalities (including counties and governmental agencies), universities, schools and hospitals. For instance, the Regional Streetlight Procurement Program (RSLPP) (a program element of PennSEF), assembles the resources to design, procure and finance the transition to LED street lighting tailored to the specific needs of 40 municipalities in eastern Pennsylvania. These 40 municipalities together represent over 700 thousand citizens. Importantly, the PennSEF model shows a slightly different iteration compared to the Delaware example: PennSEF relies on an existing authority to issue the bonds – this illustrates the flexibility of the model as it **can both rely on the creation of new authorities with bond issuing (i.e. the Delaware example) authority or can rely on existing authorities (the PennSEF example where the bond issuer is the Pennsylvania Economic Development Finance Authority).**

[236] https://www.whitehouse.gov/the-press-office/2011/12/02/we-cant-wait-president-obama-announces-nearly-4-billion-investment-energ
[237] http://www.adb.org/sites/default/files/publication/29817/second-asia-pacific-dialogue-clean-energy.pdf
[238] International investigation is, among others, documented in a 2009 special issue of the Bulletin of Science, Technology, and Society (Bulletin of Science, Technology & Society. Special issue: Sustainable Energy Utilities: new energy strategy for the new climate. Volume 29, No. 2). This special issue contains articles on SEU/SEF investigations in, inter alia, South Korean, Indian, and African development contexts.
[239] The Pennsylvania Treasury Department has partnered with the Foundation for Renewable Energy and Environment (FREE), with financial support from the West Penn Power Sustainable Energy Fund, to develop a prudent, market-based investment vehicle that promotes energy and water efficiency, clean energy generation, economic development and environmental improvement.

1.2.1.4 Benefits of a LuxSEF Application

In the context of sustainable energy finance, a series of SEF's capitalization mechanism are offered on a routine basis. Such a strategy has the following benefits:

- **Extra savings for program participants:** Under SEF program mechanics, ESCOs are incentivized to underestimate savings in order to meet established guarantees and avoid shortfall penalties. Typically, ESCOs guarantee about 96% of estimated savings.[240] Remaining performance benefits program participants. Additionally, savings continue to accrue beyond term of debt service to the benefit of program participants.
- **Non-energy benefits accrue to participants:** Non-energy benefits (e.g., operational savings or deferred maintenance) can be as much as 40% or more of the total economic savings generated by such projects.[241]
- **Avoidance of interest cost penalties for small program participants:** Through pooled financing, the program avoids possible interest cost penalties for small jurisdictions.[242] This is also recognized in Luxembourg's Third National Energy Efficiency Action Plan (p. 31): "To date, the municipalities in particular have been reluctant to use energy savings contracts. This may be explained, among other things, by the often small structures of many Luxembourg municipalities, as in general the economic benefits of savings contracts can only be achieved above a certain energy cost threshold."
- **Overcomes geographic segmentation:** Overcoming issuer size segmentation can also overcome geographic segmentation as pooled financing opens access to national/international markets to attract capital and enables rural and urban participation.[243]
- **Economies of scale open technology options:** Pooled financing realizes economies of scale in the procurement of energy conservation and renewable energy technology. Advanced, higher cost technologies become available.

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[240] Shonder, J. (2013). Beyond guaranteed savings: additional cost savings associated with ESPC projects. Oak Ridge National Laboratory, ORNL/TM-2013/108.

[241] Larsen, P.H., Stuart, E., Goldman, C.A. (2014). Current policies and practices related to the incorporation of non-energy benefits in energy saving performance contract projects. American Council for an Energy Efficient Economy Summer Study 2014.

[242] Empirical evidence for the interest cost penalty for smaller jurisdictions is provided by: a) Simonsen, B., Robbins, M., & Helgerson, L. (2002). The Influence of Jurisdiction Size and Sale Type on Municipal Bond Interest Rates: An Empirical Analysis. *Public Administration Review, 61*(6), 709-717. doi:10.1111/0033-3352.00141; and, more recently, b) Bastida, F., Guillamó, M.-D., Benito, B. (2014). Explaining interest rates in local government borrowing. International Public Management Journal, 17:1, 45-73. Doi: 10.1080/10967494.2014.874257

[243] Bastida, F., Guillamó, M.-D., Benito, B. (2014). Explaining interest rates in local government borrowing. International Public Management Journal, 17:1, 45-73. Doi: 10.1080/10967494.2014.874257

- **Unlocks deep retrofits:** Energy conservation measures with short paybacks ('low hanging fruit') can be used to unlock 'deep' retrofit options. 'Deep' retrofit options (i.e., measures with long payback periods) provide significant savings potential – case study analysis by Rocky Mountain Institute of 'deep' retrofit success stories found an average 58% energy use reduction.[244]
- **Technology portfolio approach: The** program can include a wide array of energy, water, and material conservation measures (electrical and thermal), combined heat and power (CHP), distributed generation (e.g., solar PV), microgrids, smart energy management, and transportation infrastructure;
- **Trains the market for transformative change:** Finally, the structured approach outlined in the SEF strategy primes the market, including ESCOs, issuers, bondholders, and program participants, for future deployment of follow-up bond issuances. In other words, the approach trains ESCOs to operate at a scale previously inaccessible to their project-to-project business model, educates bondholders about the benefits and potential of the program, and brings in future program participants. In effect, the program creates and nurtures an energy conservation and on-site renewable energy market that positions these energy resources as infrastructure-scale options and trains all involved to reconsider these energy choices in this manner.

1.2.2 How it could Work in Luxembourg: Application of LuxSEF

A LuxSEF deployment strategy needs to properly integrate within existing legal frameworks and leverage the strengths of the local setting, actors and financial ecoystems. In addition, as visualized in Figure 7 below, **LuxSEF application fully considers the parallel deployment of the LSDFP.** As described above, the LSDFP fulfils the communication function between project promoters and capital providers. In addition, drawing from lessons learned with community choice aggregation (CCA) models, the LSDFP could fulfil a resource aggregation function (Expansion Building Block, described in the next section).[245] Importantly, flexible application allows for LuxSEF integration into the overall mold presented in Figure 7 and operates under the explicit recognition that there is no one-size-fits-all SEF-model applicable to all jurisdictions, regional.

A LuxSEF application needs to, at least, consider the following:

[244] Rocky Mountain Institute (RMI) (2015). Deep energy retrofits using energy savings performance contracts: success stories. Rocky Mountain Institute, Boulder, CO.
[245] It is also possible that a separate authority could be established specifically tasked with this function or that an alternative existing authority is tasked with this aggregation function.

- Contrary to the SEF model as applied in the U.S. state of Delaware, where a newly established public authority is granted authority to directly issue sustainable energy bonds, the Luxembourg context suggests that using an existing authority (as is done in the Pennsylvania Sustainable Energy Finance Program, PennSEF) might be more appropriate. This is especially true when one considers that the LSDFP does not have the authority to issue bonds. To enable the LSDFP to issue bonds directly would entail the burdensome necessity to adopt specific legislation in this sense, which is not recommended (see also the info box on the LSDFP above).

- As an interface between project promoters and investors, the LSDFP is not meant to manage financial flows or raise capital itself. Issues regarding liability, regulation and supervision would be difficult to address and would risk hampering the main mission of the LSDFP as a matchmaking interface between project promoters and investors. If the LSDFP were to issue bonds or raise other funding, it would most probably duplicate capacities and expertise readily available among existing public and private sector actors (government, banks, companies etc.) with higher professional skills and means (over 3.3 trillion euros of net assets in investment funds and more than 300 billion euros AuM in Private Banking). Therefore, we would suggest that the LSDFP should rather focus on bridging the well identified communication gap between project promoters and potential investors and engage in "opportunity data mining". Therein lies its genuine added value.

- As stated above, the LSDFP would support the financing of investable projects in all the pillar sectors of sustainability (economic, social and environmental), including TIR projects (but not limited to). In this light, the range of projects accompanied by the LSDFP largely exceeds the realm of energy related projects (energy efficiency, renewables) closely associated to the SEF model. In this light, LSDFP fully incorporates energy related projects, but is not limited to the latter.

As outlined in the section on the Pennsylvania Sustainable Energy Finance Program (PennSEF, USA), existing authorities or organizations can be used to issue the bonds. As such, **there is no need for the LSDFP to broaden its mandate to include a bond issuing authority.** Instead, the LSDFP can focus on its communication and aggregation functions.

Nevertheless, the LSDFP can play a central role in the LuxSEF strategy. One such role is visualized in Figure 7. Here, the LSDFP takes up the role of aggregator and interface platform between bond issuers / investment fund / loan providers, ESCOs, and the private and public sector as participating organizations.

The various contractual agreements that make up the LuxSEF approach and tie together the participants (ESCOs, public and private program participants, bond issuer, and investment funds) need some more explanation. As illustrated in Figure 7 there are two routes available that connect participating organizations (public and private) to the bond issuer via the LSDFP. On the left hand side of Figure 7, a financing window is opened that is especially attractive to the private sector. This financing window, which can be called a “service performance” financing window, relies on contractual agreements that enable off-balance sheet debt placement but is accompanied by less aggressive savings. On the right hand side of Figure 7 a second financing window, which can be called a “guaranteed savings” financing window, relies on a different set of contractual agreements that particularly enable the public sector to pursue aggressive savings.

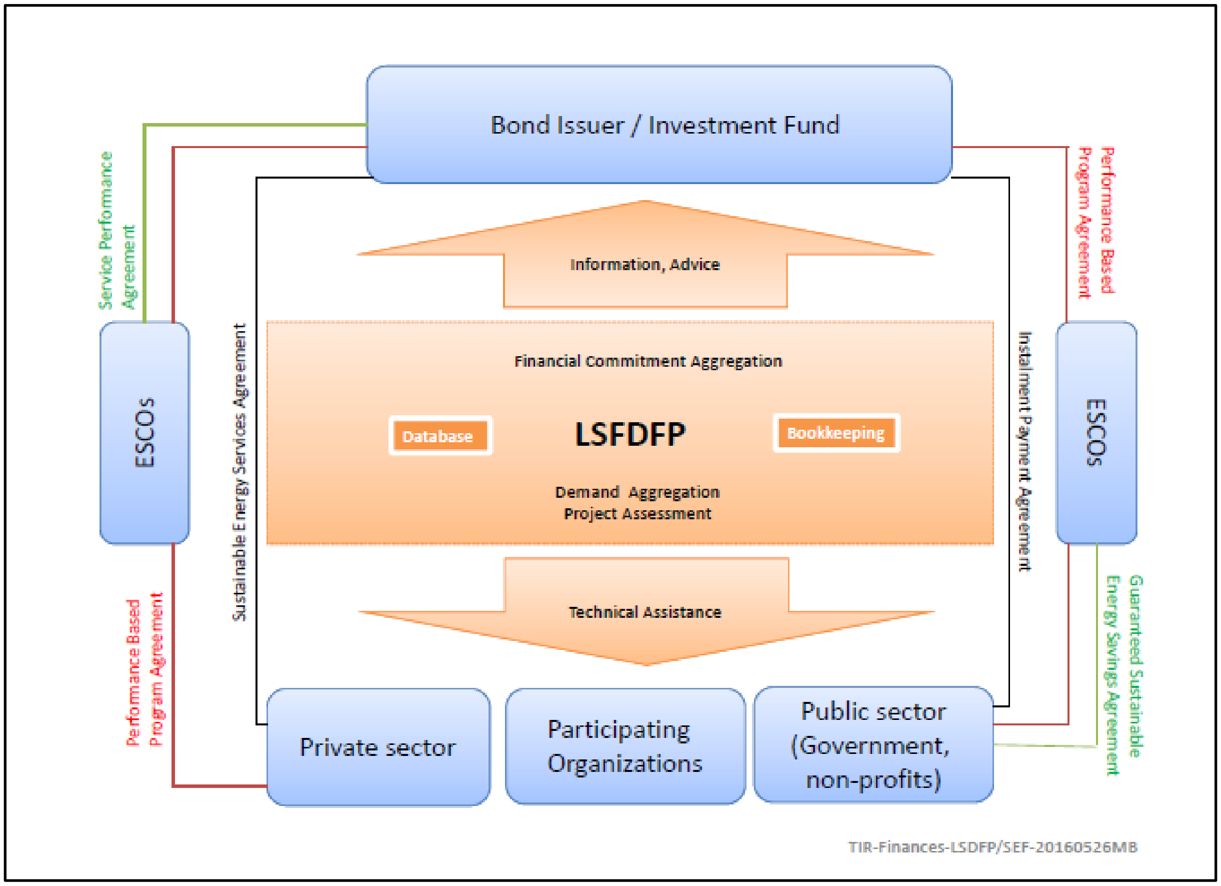

Figure 7. Overview of the potential workings of a Luxembourg Sustainable Finance Program (LuxSEF) that outlines the various contractual agreements among program participants. The LSDFP takes up a central role as aggregator and communication channel.

The strength of the LuxSEF approach lies in the program mechanics of the two financing windows. As described below, the two variants of the model operate in a similar fashion. The key difference between the two variants is the structuring of energy savings and billing. In particular, debt raised under the guaranteed savings variant is placed on the books of the program participants. Such debt obligations are typically less attractive to the private sector and, indeed, this variant of the model has been successfully applied in a public sector context. The guaranteed energy savings model does allow for more aggressive energy savings and unlocks longer investment options with longer payback periods.

The second variant, the sustainable energy services option, bills the cost of energy savings on a per kWh basis to the program participant. This bill can be an add-on to existing municipal billing (e.g., waste, sewer, etc.). Program participants, under this variant of the model, do not carry the debt on their books – they have only an obligation to provide payment for delivered services. Paying off investments through monthly or bi-monthly billing cycles (much like a power purchase agreement but now for savings), is typically more attractive to the private sector. However, overall, the second variant is less capable of unlocking very aggressive savings opportunities.

Program Mechanics of the LuxSEF Guaranteed Energy Savings Variant

In Figure 7 the right hand side of the illustration notes several contractual agreements: a) a guaranteed energy savings agreement (GESA), b) a performance based program agreement, and c) an Installment Payment Agreement. To provide insight into LuxSEF functioning as described throughout this document, it helps to provide the various program steps that makes up the guaranteed energy savings financing window:

1. First, the LSDFP performs its communication and aggregation function. This includes surveying potential project promoters (both public and private) that are interested in participating in the LuxSEF program. Interested public and private project promoters sign a non-binding letter of interest (LOI). This group represents the pool of participating organizations that will enter into the various contractual arrangements with the ESCOs and the bond issuer.
    a. A separate element not shown in Figure 7 is that the LSDFP, if properly enabled, could perform a pre-qualification of ESCOs that can participate in LuxSEF. Such pre-qualification raises participating organizations' confidence in the program. Pre-qualification of ESCOs furthermore facilitates a smooth roll-out of the program.
2. Participating organizations select one of the prequalified ESCOs – facilitated through technical assistance and advice from the LSDFP –to perform a no-cost, pre-contract audit. The selected ESCO presents an initial proposal based on the pre-contract audit. This step provides participating organizations insight into their energy consumption patterns and identifies potential saving and renewable energy opportunities.
3. Next, the participating organizations enter into Guaranteed Sustainable Energy Savings Agreements (GESAs) with the selected ESCOs. GESAs describe conservation services and onsite clean energy generation services and defines service performance guarantees. All guarantees are expressed in monetary amounts.

4. Participating organizations, ESCOs, and the Issuer enter into multi-year, performance-based Program Agreements outlining data reporting, criteria for measurement of services, job creation, etc.
5. The issuer of the bond enters into Installment Payment Agreements with participating organizations. Participating organizations agree to make payments for installation of on-site clean energy and energy efficiency upgrades.
6. If authorized, the issuer dispenses (tax-exempt) by-appropriation bonds secured by payments under the Instalment Payment Agreement. Alternatively, the issuer engages with loan providers to raise the level of capital required.

The LuxSEF Sustainable Energy Services Variant

The second variant of the SEF investment model, incorporates components and lessons learned from tested financial frameworks such as on-bill financing, property assessed clean energy (PACE), and power purchase agreements. As mentioned, this approach is typically seen as more attractive to the private sector due to its handling of the debt. The program mechanics of this variant operate in much the same way as suggested in Figure 7:

1. First, the LSDFP performs its communication and aggregation function. This includes surveying potential project promoters (both public and private) that are interested in participating in the LuxSEF program. Interested public and private project promoters sign a non-binding letter of interest (LOI). This group represents the pool of participating organizations that will enter into the various contractual arrangements with the ESCOs and the bond issuer.
    a. A separate element not shown in Figure 7 is that the LSDFP could perform a pre-qualification of ESCOs that can participate in LuxSEF. Such pre-qualification raises participating organizations' confidence in the program. Pre-qualification of ESCOs furthermore facilitates a smooth roll-out of the program.
2. Participating organizations select – facilitated through technical assistance and advice from the LSDFP – one of the prequalified ESCOs to perform a no-cost, pre-contract audit. The selected ESCO presents an initial proposal based on the pre-contract audit. This step provides participating organizations insight into their energy consumption patterns and identifies potential saving and renewable energy opportunities.
3. Next, the participating organizations enter into Sustainable Energy Services Agreements with the issuer. Participants agree to pay issuer for the sustainable energy services

(including conservation and onsite clean energy generation) delivered during the term of the agreement (much like a PPA).

4. Participating organizations, ESCOs, and the Issuer enter into multi-year, Service Performance Agreements describe conservation measures and onsite clean energy generation, and define performance guarantee(s).
5. The issuer of the bond enters into a Program Agreement with participating organizations and ESCOs outlining data reporting, criteria for measurement of services and job creation.
6. The issuer issues (tax-exempt) by-appropriation bonds secured by payments under the Instalment Payment Agreement. Alternatively, the issuer engages with loan providers to raise the level of capital required or alternative routes for capital provision.

1.2.3 LuxSEF Challenges, Barriers, and Opportunities

1.2.3.1 Financial and Policy Conditions

As the leading center for investment funds in Europe (2nd worldwide), Luxembourg's financial expertise is well-positioned to apply the SEF sustainable energy financing strategy. As noted in the 2015 Article IV consultation by the International Monetary Fund (IMF), Luxembourg has a stable political environment, a financial hub that serves all of Europe, and a central government net asset position of about 20 percent of GDP which positions Luxembourg as one of two Euro area sovereigns rated 'AAA' by all major rating agencies.[246]

A European Commission Staff Working Document assessing the Luxembourg economy as part of the European Commission's annual growth survey also highlights the critical importance of the financial sector as the main engine of economic growth.[247] However, the staff working document reveals several weaknesses that could be of importance in the deployment of a SEF strategy. For instance, while the existing vehicle fleet in Luxembourg is becoming greener and more fuel-efficient, current mobility conditions are far from the government's sustainability objectives. High motorisation rates and the insufficient supply of public transportation – a key objective of the Luxembourg government is to increase public transport in all motorised forms from 14.5% in 2009 to 25% in 2020 – make mobility difficult. In terms of energy efficiency and renewable energy objectives and targets, the document notes that further integration of smart grid deployment is critical. Overall, Luxembourg is found to be on a path that will not meet its

[246] International Monetary Fund (IMF) (2015). IMF country report No. [15/144]. Staff Report for the 2015 Article IV Consultation. Washington, DC: International Monetary Fund.
[247] European Commission (2016). Country Report Luxembourg 2016. Commission Staff Working Document (SWD2016 84 final).

Europe 2020 targets concerning non-emission trading scheme greenhouse gas emissions. Increased levels of investment are required.

Environmental fiscal reform opportunities exist in Luxembourg as well: Luxembourg has among the lowest scores of the EU member states on enacting taxes to address energy efficiency and sustainability in the mobility, construction, agriculture, and water sectors.[248]

1.2.3.2 Green Bond Market

The Delaware SEU sustainable energy bond was the first of its kind to be issued in the United States. The DE SEU $72.5 million bond offering is a part of a larger 'green bond' market. Europe in general, and Luxembourg in particular, are strong promoters of the green bond market. Indeed, Luxembourg offers an ideal environment for climate finance as it can be seen as the world's green bond capital.[249] In addition, Luxembourg is well-positioned to drive and benefit from further green bond market growth. For example, the Luxembourg Stock Exchange (LuxSE) was the first stock exchange to list a green bond in 2007. Today, with more than 80 green bonds listed by 20 issuers in 19 currencies, LuxSE is by far the leading exchange at international level for this asset class.

In 2007, the European Investment Bank (EIB) pioneered the green bond option and, to date, the EIB is the largest green bond issuer with €10 billion issued. Of particular interest in the context of a Luxembourg SEF approach is the EIB's repositioning of its role in the green bond market: green bond issuance is now an "autonomous strategic goal" of the EIB's Corporate Operational Plan 2015-2017. The EIB's Climate Awareness Bond (CABs) series is a solid example of this new objective: the EIB is building a benchmark yield curve and has, so far, issued five CABs in EUR to raise the profile of the market. The current CAB yield curve sports three benchmarks: a) one €400 million issuance at 11/2019 (4 years) maturity and 1.34% interest; b) two 11/2023 (8 years) issuances, one €400 million and the other €600 million, both at 0.5% interest; and c) two 11/2026 (11 years) issuances at €250 million each and both at 1.25% interest. The EIB is, therefore well positioned to support the SEF approach in conjunction with the Luxembourg financial centre.[250]

[248] European Commission (2016). Study on assessing the environmental fiscal reform potential for the EU28. Eunomia Research and Consulting, IIEP, Aarhus University.
[249] LuxembourgForFinance (2016). Financing climate change action – find out why Luxembourg offers an ideal environment for climate finance. Document can be accessed at: http://www.luxembourgforfinance.com/en/financing-climate-change-action
[250] The roll-out of further green bonds is supported by the market's increasing attention to environmental and financial integrity through the Green Bond Principles. However, to use the green bonds as a part of a larger

With the recent signing of the COP-21 Paris Agreement on climate change, the green bond market can be seen as entering into a new stage where policy drives market growth. This is in contrast to a) the first stage of the green bond market (roughly 2007-2011) where, especially multilateral development banks assured market growth and b) the second stage of the market (roughly 2011-2014) where investors and intermediaries became primary drivers of market evolution. The market is growing rapidly: the London-based Climate Bonds Initiative, for instance, catalogued a $41.8 billion market in 2015 while issuance was already at $23.2 billion (as of May 2016) and expected to reach $100 billion by the end of the year.[251]

1.2.3.3 Luxembourg ESCO Market

The ESCO market in Luxembourg will require further refinement. The 2014 Joint Research Centre (JRC) study on the European ESCO market, for instance, notes that "information about the [ESCO] market or the companies working in Luxembourg is difficult to find. The ESCO market is not active, and the latest reliable information is from 2007, when 3-4 foreign companies were found to offer energy service solutions for Luxembourg".[252] While data is scarce, the Third National Energy Efficiency Action Plan (NEEAP) outlines that the ESCO market in Luxembourg is experiencing growth and sees the potential to develop the energy services market as 'high'. The document also notes that pilot energy saving contract projects are underway. Overall, however, it appears that further development of the energy services market, in particular the development of ESCOs capable of participating in an SEF program at the proposed scale might be required.

To overcome such potential obstacles, the Grand Duchy of Luxembourg will need to incentivize the creation of ESCOs, certify proper training and performance, guarantee early adoption with the transformation of all government and public buildings into Internet of Things nodes, and provide government-supported training for thousands of semi-skilled, skilled, and professional workers that will be needed to transform the Luxembourg building and other asset stock.

Under the vision outlined here, the LSDFP is the one-stop-destination for financial contributors and project promoters alike. The LSDFP is an innovative public-private partnership delivering energy efficiency, load reduction, clean energy services, material savings, transportation investment, digitalized monitoring and verification and a range of other technologies and

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collective action strategy, the market will be reliant on further efforts to maintain current standards. Support policies could be formulated at the EU level to advance the market.

[251] https://www.climatebonds.net/

[252] Bertoldi, P., Boza-Kiss, B., Panev, S., & Labanca, N. (2014). European ESCO Market Report 2013. Joint Research Centre Science and Policy Reports. Publication by the European Commission.

options. The creation of a LSDFP fits with the larger policy context and direction. For instance, the Third NEEAP is considering the creation of a public financial institution to facilitate investment in energy efficiency and renewable energy.

1.3 Establishing a Resource Aggregation Capacity

While the Luxembourg Sustainable Energy Finance (LuxSEF) model provides a useful aggregation of demand-side projects (whether energy-efficiency upgrades or rooftop photovoltaic systems), there are other complementary institutional arrangements that the LSDFP may want to consider to drive greater investments in renewable energy and energy efficiency upgrades at an equivalent national or community scale. One such model is a complement of energy cooperatives, referred to as Community Choice Aggregation (CCA). CCA is a vehicle that enables community governments to aggregate or pool energy customers to purchase and develop energy resources, as well as to administer energy programs, on behalf of their residents and businesses. This institutional arrangement allows the local community to shape the CCA program to prioritize desired benefits, including but not limited to, increased investment in renewable energy sources and energy efficiency, economic development, carbon reduction strategies, and workforce development efforts.[253]

Like energy cooperatives, CCAs have the authority to buy and/or develop energy resources on behalf of the residential, commercial, and government energy customers within its jurisdiction. Whether heat or electricity, the energy continues to be distributed and delivered over existing pipelines, electricity lines, and other infrastructure that is owned by a private company or investor-owned utility.

By establishing a CCA program, cities and cantons can take increased ownership and control over their electricity generation and consumption. More than just buying and selling electricity, a CCA provides a platform for managing the community's energy resources through the administration of energy efficiency programs, as well as the through the development of local renewables. Indeed, some local communities have been motivated to form community choice programs as a means to achieve greater levels of renewable energy generation, encourage local investment in energy resource development, reduce greenhouse gas emissions, amplify the

[253] With origins in the State of California, CCA is statutorily enabled in California, Illinois, Ohio, Massachusetts, New Jersey, New York, and Rhode Island with a handful of other states considering legislation. For more background on the idea of a Community Choice Aggregation model as it might be applied in the Netherlands or the region, see the resources of Local Energy Aggregation Network (LEAN Energy US) at http://www.leanenergyus.org/. For a quick review of energy cooperatives in Europe, see the Navigant report cited in footnote 1 of this overview.

community's level of energy efficiency, and catalyze electricity grid modernization efforts.[254] These investments in a cleaner and more efficient mix of energy resources, in turn, tend to stimulate more immediate job creation while also reducing the cost of energy services for all customers. For example, current aggregation contracts in the Midwestern part of the United States are yielding up to 25 percent rate savings while rate savings on the East coast are averaging savings of 10 to 14 percent (as of September 2013).[255]

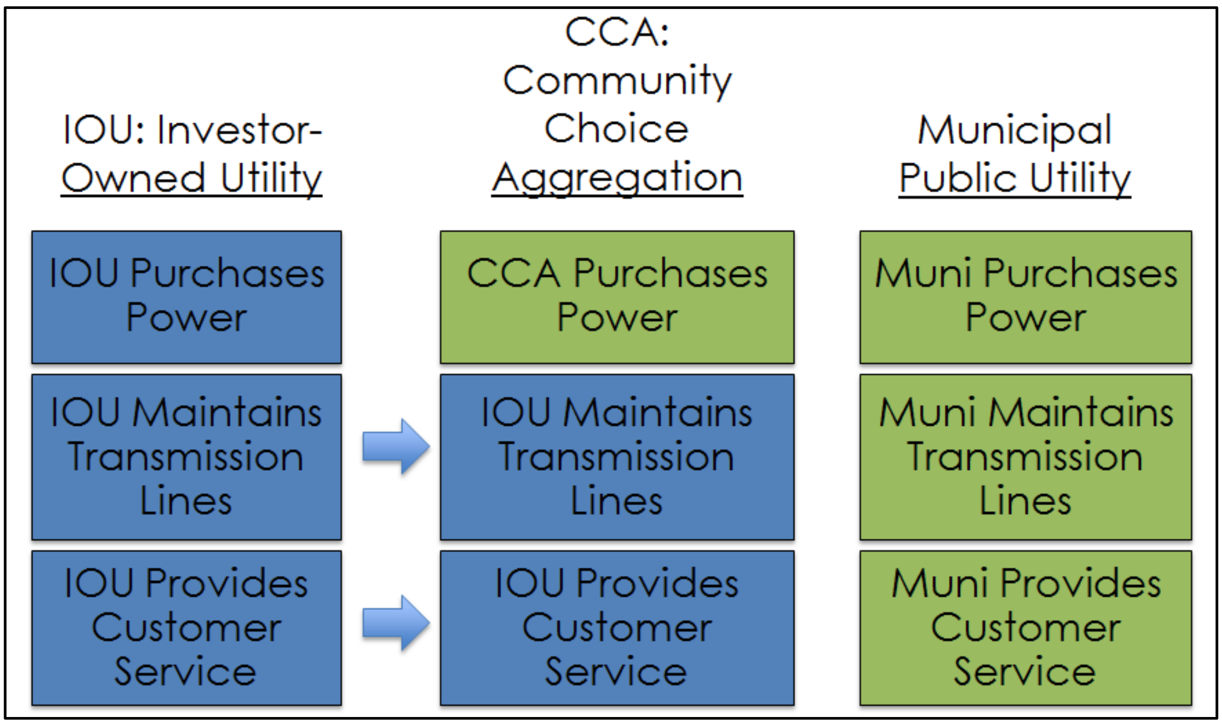


Figure 6. Comparing the Community Choice Aggregation Authority Model with Private and Public Utilities [256]

Source: http://www.leanenergyus.org/what-is-cca/

As explained by LEAN Energy US, an energy aggregation authority can be done on an opt-in or opt-out basis (depending how the CCA or public authority is constituted). But, as they note: "the most common and successful programs are opt-out. This means that consumers are

[254] Gordon, M. (2014). CCA and Microdgrids: Community Driven, Private Enterprise Models for Smart Grid Innovation.

[255] The data are from footnote 3 in the explanation offered at: http://www.leanenergyus.org/what-is-cca/.

[256] While this example draws on the business model of the electric utility, it could also be extended to include the development, bulk purchase and distribution of transportation fuels, industrial chemicals, water resources, and more.

automatically enrolled after a successful public referendum at the local level, as was done in Illinois and Ohio; or, enrolled when their local elected representatives (city council or county board) voted to form or join a CCA program, as happened in California. The opt-in approach is voluntary but participation rates are traditionally very low which reduces the value of group purchasing and makes it harder for local programs to achieve economic viability. Opt-out aggregation achieves the necessary market scale for effective group purchasing, but allows a customer to switch back to utility service or another energy provider at any time. Either way, customers always have the choice to stay or go."

LEAN Energy US further explains: "Because CCA is a revenue-based system—not government subsidized—such programs are self-supporting from an existing revenue stream." In other words, the energy costs that consumers pay to a retail energy supplier or an investor-owned utility "are bundled and redirected to support the group purchase of energy through a local CCA program." This can apply whether the service provided is natural gas or electricity, but it could also be fuel oil or other energy carriers. As shown in Figure 8 above, there is a clear separation between energy production and the actual distribution of the different energy resources. As envisioned here, the partnership with an existing energy supplier as the primary distributor is one that is negotiated and established within the existing market structure. In California, for example, the local utility has entered into a partnership with the CCA authority. In this instance, the retail energy provider benefits from the group purchasing power through lower costs. As LEAN Energy US notes, the utilities or other energy supplies are "made whole" through cost recovery surcharges (or exit fees), also covering reasonable profits, as they lose energy sales. At the same time, the energy supplier retains its ownership and management of "the distribution infrastructure, and all final energy deliveries, repairs, billing, and customer service functions."

How might such an authority be administered? In the State of California, there are currently three management options. The most common approach is through an inter-jurisdictional joint powers agency (JPA) that serves as a public, non-profit agency on behalf of the municipalities that choose to participate in the CCA program. This is the model under which Marin Clean Energy and Sonoma Clean Power operate, for example. A second option is a single city or county that might structure a CCA through an Enterprise Fund; this is the model under which Lancaster Energy Choice in California operates. In this option, the CCA is managed "in house" as a separate program/fund within existing municipal or government operations. Still a third option involves a commercial or third party management where the CCA's operations are delegated by contract to a private firm. This model is new in California so its risks and benefits are yet to be fully vetted or realized.

What specific approach makes the most sense for Luxembourg? That remains open as it will also depend on how the LSDFP/SEF might complement the operations and purposes of the CCA.

Yet, this authority provides the means to further increase and organize the flow of energy resources in ways that enhance LSDFP/SEF. In fact, new tools are now in play as blockchains are giving more power to individual consumers to negotiate without a single authority and match energy resources with specific energy demands.[257]

1.4 Deployment of the Sustainable Development Finance Strategy

The application of the Sustainable Development Finance Strategy, as described in the above sections, can facilitate and accelerate the deployment of sustainable energy technologies throughout all sectors of the economy. A series of key steps flow from the three building blocks:

1. **Creation of the Luxembourg Sustainable Development Finance Platform (LSDFP):** The LSDFP takes up a central role and acts as a one-stop-destination for capital providers and project promoters (both single and aggregated).
2. **Introduction of LuxSEF:** The LuxSEF strategy is introduced as a key mechanism that structures financing between aggregated pools of supply and demand, drives finance supply, and provides project portfolios at infrastructure scale. The LSDFP plays a central role in the establishment of the contractual arrangements between ESCOs, bond issuer/loan providers, and program participants. To do so, the LSDFP relies on a team of technical, legal, financial, and policy experts. Any financing at the scale discussed here will require a trusted advisor participant – a party that is not profit oriented and represents program participants to ensure savings guarantee obligations are met.
3. **LSDFP prequalifies ESCOs** based on their capacity to fulfil program operations, including their size, pricing, etc. In doing so, LSDFP provides a strong market signal to the ESCO market to develop in the direction of infrastructure-scale energy efficiency and on-site renewable energy generation provisions.
4. Interested parties sign **a non-binding letter of interest (LOI)** and discuss their specific goals, timeline, energy patterns, etc. with LSDFP.
5. The **LSDFP brings together ESCOs and interested program participants**. ESCOs perform no-cost, pre-contract audits and present initial energy savings proposal. Participants sign guaranteed energy savings agreement with their selected ESCO. Guaranteed energy savings

[257] Aviva Rutkin, Blockchain-based microgrid gives power to consumers in New York. 2 March 2016. In this case, while solar panels on the roofs of terraced houses in New York City soak up sunshine, a pair of computers connected to the panels quietly crunch numbers, counting how many electrons are being generated so that they can be bought and sold as needed to neighbors rather than go through a central authority or utility. This project, run by a startup called Transactive Grid, is the first version of a new kind of energy market, operated by consumers, which may very well change the way we generate and consume electricity. Although not referenced here, these arrangements can also include much more than heat and power, but also transportation fuels, water resources, and the flow of other materials, goods and services within the Duchy of Luxembourg.

agreements include an investment grade audit, a construction proposal, a savings guarantee, and a proposal for measuring and reporting savings each quarter.

The SEF strategy, under a LSDFP platform, can be extended to the rest of the European Union. Here, too, it is important to remember that there is no one-size-fits-all solution for implementing SEF models. It is, therefore, worthwhile to note that SEF models always require being properly calibrated to local settings. Nevertheless, with its first mover advantage, lessons learned, and otherwise gained expertise, Luxembourg can recommend regions and other member states to establish similar kinds of finance structurings, specialized to the context of those communities.

The Sustainable Development Finance Strategy can be captured in a visualization depicting its potential value and ease of implementation. As indicated in the illustration below, the Sustainable Development Finance Strategy can be positioned as a “flagship proposal” – a proposal that Luxembourg can proceed to fund, design, build, and implement as a highest priority. To arrive at the illustration, the Sustainable Development Finance Strategy was scored along two dimensions: ease of implementation and potential value. A total integrated project score of **89 points (out of 100)** is achieved. The scoring breakdown is provided below:

<u>Proposal “1”: A Sustainable Development Finance Strategy:</u>

Value Factors

- *Reduces final energy consumption*: Assigned score is High (5), Weighting is 2, total score is **10**
- *Reduces CO_2 emissions*: Assigned score is High (5), Weighting is 3, total score is **15**
- *Increases % of renewable energy*: Assigned score is High (5), Weighting is 2, total score is **10**
- *Provides knowledge in subsequent projects*: Assigned score is High (5), Weighting is 1, total score is **5**
- *Supports multiple TIR pillars*: Assigned score is High (5), Weighting is 1, total score is **5**
- *Strengthens Luxembourg assets*: Assigned score is Med (3), Weighting is 1, total score is **3**

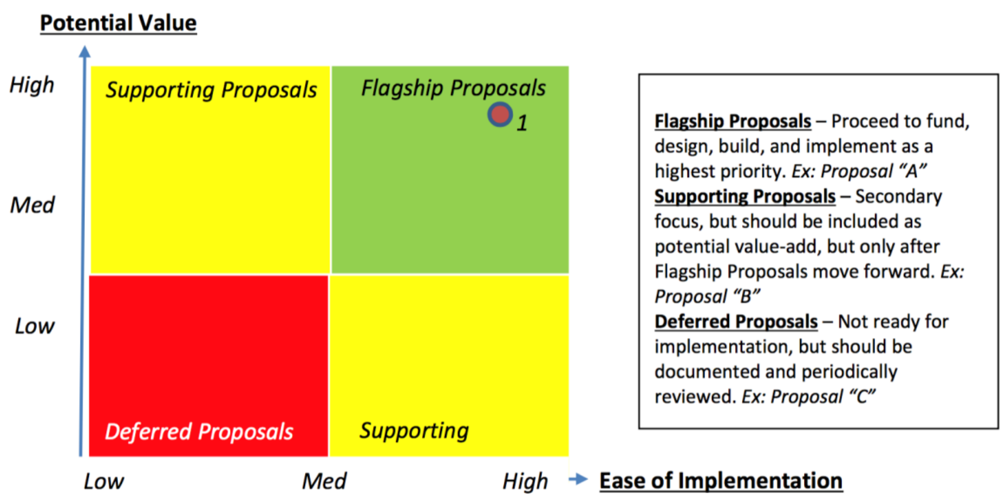
Total Value Score = **47** points (y-axis).

Implementation Factors

- *Technology commercially available*: Assigned score is High (5), Weighting is 1, total score is **5**
- *Requires specialized skills or partners*: Assigned score is Med (3), Weighting is 1, total score is **3**

- *Provides an upscalable platform*: Assigned score is High (5), Weighting is 2, total score is **10**
- *Requires minimal decommissioning*: Assigned score is Med (3), Weighting is 1, total score is **3**
- *Can be self-funded*: Assigned score is High (5), Weighting is 3, total score is **15**
- *Requires little start-up time*: Assigned score is Med (3), Weighting is 2, total score is **6**

Total Implementation Score = **42** points (x-axis).



Proposal 2: The Blockchain Opportunity for Luxembourg

Blockchains are an essential new technology for ensuring a more efficient, transparent, and secure transaction-based economy. While there are very real concerns about security risks associated with any information-based technologies, there is broad agreement that blockchain technology presents a unique opportunity for the Grand Duchy of Luxembourg to lead a global transformation in both energy and economic efficiency. This can, in turn, lead to greater inclusiveness and vast potential wealth creation. Blockchain technology is so integral to the digital economy of the future that many of the ten bold projects envisioned by the Financial Working Group's contributions to TIR's Smart Luxembourg initiative cannot be optimized in its absence.[258]

Over the past year, interest in blockchain technology, the distributed ledger system that underpins bitcoin and other digital currencies, has surged internationally. The world's biggest banks, largest consulting firms, most influential non-government organizations and, recently, leading national and regional governments and central banks are all exploring blockchain technology's potential. More critically, there is now widespread belief that this technology will

[258] Early use of blockchain technologies required energy-intensive applications that might have partially offset the full benefits of their use. At the same time, however, both research and advances in technologies indicate a rapidly growing improvement in their application so that anticipated energy needs by 2020 may be only three percent of what was previously anticipated. See, for example, an interesting analytical exercise suggesting that *worldwide use of the technology could consume as much power as Denmark, but probably won't*.

usher in sweeping new efficiencies globally by cutting out middlemen and empowering end-users and start-up innovators. Blockchain solutions are now being applied to everything from the real-time supply of renewable energy resources at the neighbourhood level, to settlement of stocks and bonds and the copyrighting of digital music.

The Blockchain is a breakthrough that heralds the Internet's next evolutionary phase and provides the best existing technology case for effectively realizing the Third Industrial Revolution. The first Internet phase, led by the development of the World Wide Web in the 1990s, vastly decentralized communication, while providing unprecedented access to information. But it left in place an uneven playing field dominated by gatekeepers that meant that inefficiencies and a lack of interoperability persisted, especially in finance, all because the Internet could not solve society's dependence on a centralized system of trust. In this second, blockchain-led phase, developers are building the so-called "Internet of Value," a system of peer-to-peer information exchange founded on a distributed trust network within a distributed and decentralized system of governance. The Blockchain is generating new paradigms of trust and accountability and it is evolving into a borderless, ownerless architecture upon which myriad new applications will be based.

Luxembourg is uniquely positioned to exploit this ground breaking technology. Sitting in the middle of Europe and having already established itself as a financial powerhouse, the country has an opportunity to grab a global leadership role in the Blockchain's development. By moving early, it can bring efficiencies to its own economy, helping to reverse a worrying decline in total-factor productivity and competitiveness. As discussed later, it can then export that knowledge and related services to Europe and the rest of the world, dramatically scaling up the well-being of Luxembourg citizens.

Luxembourg's strong digital foundation also works to its advantage. With penetration of ultrafast broadband and Internet usage among the highest in the world, there's greater potential for the network effects needed for the blockchain to succeed. Critically, the country enjoys a disproportionately large population of highly trained software developers, with the University of Luxembourg hosting a renowned school of cryptology – the discipline that lies at the heart of all blockchain design. The Luxembourg School of Business has already hosted a "blockchain bootcamp" to stir interest in the field. The ongoing development of this technology will ensure that the world's top cryptographers will constantly be in short supply. However, Luxembourg is not alone in these global efforts and must act quickly to gain advantage.

But there is work ahead. A KPMG Luxembourg survey, as but one example, found that only 17 percent of asset management CEOs are worried about disruptive technologies such as the blockchain.[259] This suggests Luxembourg's biggest industry may be vulnerable to the reality taking hold around it. But it can seize an opportunity if it incentivizes its fund-management industry to move faster than those in other financial centers. In a world of open data, where transactions and value exchanges of all sizes flow fluidly across borders and disparate jurisdictions -- as well as across and between humans and "Internet of Things"-connected devices -- many of these initiatives will demand distributed trust. Any embrace of "robo" financial advice, by way of example, will require that investment algorithms are subject to real-time audits which can be enabled by the Blockchain's immutable record of changes of state. That same tamper-proof ledger can also record and prove people's self-sovereign assertions of identity, the bedrock of the ambitious data vault project aimed at facilitating seamless, digital execution of citizens' personal and property rights.

The blockchain allows the issuance of the unique digital assets and crypto-securities, turning crowdfunding schemes into liquid marketplaces for new capital formation. It's also an interactive accounting platform with which government agencies and/or private institutions can issue local B2B and B2C currencies to boost the internal economy in a manner that assures users that their counterparts won't renege on credit obligations. And it must feature heavily in any green finance plan to fund energy projects at home or abroad, both because the blockchain offers auditability of key data on carbon savings and because it allows for financial aggregation and securitization of small, decentralized community installations.

Regulation can be both the killer and the enabler of innovation in this field. With that in mind, Luxembourg's government should approach it as it has other such opportunities, seizing on regulatory innovation and reform opportunities to encourage new technologies and markets. The Grand Duchy's dominance in asset management and banking demonstrates how this approach can let it carve out an international role and foster a high-value-add, wealth-generating export industry. This was seen in its proactive adoption of the first UCITS directive of 1985, which turned Luxembourg into the second-largest fund management center in the world and, more recently, in its move to encourage family offices to domicile in the country. The country now has an opportunity to do the same again as early-stage regulatory guidelines emerge around the blockchain and virtual currencies. Luxembourg has already moved quickly to grant licenses under the EU's new "BitLicense" rules to firms such as payments provider SnapSwap and bitcoin exchange BitStamp. Service providers such as bitcoin wallet and analytics firm Blockchain -- which adopted the name of the ledger as its own -- have been so encouraged by this approach that they set up headquarters in Luxembourg.

[259] KPMG, "Management Company CEO Survey 2016," p. 6. http://www.kpmg.com/LU/en/IssuesAndInsights/Articlespublications/Documents/Management-Company-CEO-Survey-032016.pdf

Beyond finance, other key growth areas for Luxembourg to diversify its economic exposure include biotech, logistics and energy, and especially greater energy productivity. As many new applications for blockchain technology emerge, the government can and should capitalize on these early successes by inculcating a startup-friendly regulatory space, not only to encourage innovation but also to drive the agenda in Brussels and Frankfurt, setting standards for the future evolution of regulations. The BitLicense rules, for example, are a work in progress; affording Luxembourg room to leverage its respected status as a trusted center for financial management and break new ground. At the same time, local regulators should closely monitor legal developments in competing jurisdictions such as the U.K., which is aggressively positioning London as a fintech hub. Ideas for innovation-friendly regulation can be lifted from the U.K. Financial Conduct Authority's "fintech sandbox" concept in which it has designed a "light touch" pro-innovation regulatory framework for start-ups. Additionally, some insights might be gained from examining the Greater Zurich Area's push to domicile as many blockchain companies as possible.

In particular, there's an important opportunity to explore "regtech" ideas emerging out of the blockchain ecosystem. The transparency, traceability and immutability of blockchain ledgers means that -- contrary to the earlier, less well-informed view that the anonymity of bitcoin creates an escape route for criminals -- they can be a powerful tool for law enforcement. Europol has recognized this by signing a MoU with blockchain analytics firm Chainalysis. When Big Data analysis is applied to the blockchain, regulators are finding it produces a rich trove of information. In the U.S., for example, Homeland Security is developing a blockchain analytics prototype. Meanwhile, a Washington-based group called the Blockchain Alliance is engaging leading digital currency firms in a collaborative working group with seven major agencies: Homeland Security, the Department of Justice, the FBI, the IRS, the Secret Service, Immigration and Customs Enforcement, the U.S. Marshals Service, and the Commodity Futures Trading Commission.

The greatest potential may lie in breaking the paradigm of analog ID and delegated KyC/AML regulation for money transmission, which has kept billions of people out of the global financial system yet also failed to prevent an estimated $2 trillion in annual money laundering worldwide.[260] Leadership for more flexible yet robust system can come from CSSF, which is already using Big Data analysis to enhance its surveillance efforts.[261] When applied to the

[260] United Nations Office on Drugs and Crime, "Money Laundering and Globalization," https://www.unodc.org/unodc/en/money-laundering/globalization.html

[261] KPMG, "Management Company CEO Survey 2016," Interview with Simone Delcourt, Director, Commission de Surveillance du Secteur Financier. p. 7-8. http://www.kpmg.com/LU/en/IssuesAndInsights/Articlespublications/Documents/Management-Company-CEO-Survey-032016.pdf

blockchain, these sophisticated analytics create ostensibly anonymous user profiles that are extremely effective for discovering money launderers and terrorist financiers and for demonstrating the harmlessness of other transactions made by many poorer economic agents that lack traditional ID.

In effect, these data-bundling profiles are a form of identity and, when combined with device identity protocols, can empower regulators to block targeted nodes of illicit activity while keeping healthy financial transactions flowing -- even in the absence of personal identifying information (PII.) As we move to a more complicated global financial system with multiple digital currencies, micropayments and machine-to-machine transactions within the Internet of Things, this kind of digital ID approach will be critical. The CSSF could take a lead here, pushing the EU into the cutting edge of money transmission regulation.

Regtech ideas that are based on the blockchain should also be explored as a means of overhauling the oversight of financial entities and money service businesses. Robust "multi-sig" protections, for example, in which funds cannot be moved out of an account unless signed by a combination of keys, could greatly enhance consumer protection and allow for less burdensome capital requirements on financial startups. Designed appropriately, these new systems can make it virtually impossible for a custodian to lose or steal a customer's digital-currency funds -- in fact, with the customer holding one of the keys, it challenges the very definition of "custody." Similarly, the Blockchain's powerful audit capabilities allow real-time proofs of reserves; institutions can unquestionably demonstrate solvency to regulators and customers alike, at any time of their choosing. This should both enhance regulatory oversight and obviate the need for time-consuming, costly quarterly reports that are out of date by the time they are delivered.

Additional Core Blockchian Concepts for Luxembourg to Consider

The Blockchain gives rise to a number of core concepts with which to build a more versatile and robust governance infrastructure for an economy. Examining these concepts helps to frame the various options facing the Luxembourg government. We will explore four in particular -- the **device identity model**, **anchoring**, **tokenization** and **smart contracts** -- and highlight their application to potential projects that the government could pursue.

2.1 Identity and the Blockchain

The Blockchain introduces the Device Identity Model, a revolutionary approach to digital identity. Traditional digital identity systems rely on *shared secrets* and *institutional endorsements*. Under that model, when a user creates an account with a service, the service asks the user to choose a *secret password*, and then attempts to verify an email address by mailing it a *shared secret* link or code. Banking, and other services that have identity-based regulations also request *verifiable personal secrets* like previous addresses, mother's maiden names, and even a taxpayer's ID number or a state issued ID like a driver's license and passport. These systems build large, centralized databases of personal ID information that are used to verify identities. As centralized repositories, they become single-vector targets, inherently vulnerable to increasingly sophisticated cyber-attacks. That means that at the same time that the value of the information contained in them increases over time, they also become *less secure over time*. One paradoxical result is that identity theft, fraud and other breaches of the identity system are easier to perpetrate against older people with identities that have accrued more value.

With the Blockchain, instead of tying blockchain-related transactions to accounts with usernames and passwords, transactions are controlled by a ***collection of related encryption certificates.*** This is the ***device identity model*** and, when combined with the immutability of the Blockchain ledger, it has major benefits for security and privacy.

Most people in Luxemburg own a variety of devices capable of cryptographic authentication, such as a smartphone, a tablet, a desktop or laptop computer. Increasingly, also, computing devices are embedded into machine-to-machine networks within the so-called Internet of Things. As the locus of authentication shifts to the user's devices the would-be attacker's target also shifts. Rather than fraudulently presenting themselves as any of the users of a service to break into its database (or simply downloading a copy of the hacked database online) the attacker that's confronting the *device identity model* must compromise the actual device in the user's possession. The result is much less value per attack.

As more and more online services leverage the *device identity model*, expect identity fraud to more intensely concentrate on older systems that still rely on *shared secrets* such as passwords and Government ID numbers. Important applications like Facebook and ApplePay already rely on Device Identity to protect their systems, but the Blockchain was the first to exclusively rely on it. Additionally, because the ledger is distributed across a wide array of computers and is constantly validated by that network, the security around the information generated by those devices is also profoundly more secure than anything held on a centralized database.

The concept will be vital to the Luxembourg Financial Working Group's proposal for a data vault of citizens' personal and property information with which they will use *smart contracts* to transact with each other, with corporate entities and with the government. Given the imperative of securing this highly sensitive pool of data -- and, in so doing, strengthening financial and government security while protecting personal privacy --, a transition from shared secret systems of identity to device-mediated ones secured on the Blockchain will be important. Rather than "Band-Aid" solutions to increasingly vulnerable centralized databases, the Blockchain embeds security into its core distributed architecture.

Amid the shift to the *device identity model,* users will demand a mix of multi-factor authentication, likely including encrypted biometrics, to secure their exclusive access to each device. The information and protocols pertaining to those factors cannot reside on the device itself, but neither can it be stored in centralized database, which would recreate a vulnerable attack vector for the most sensitive of all personal information. Instead, the Blockchain could be used to mediate permissions via each actor's unique private key access, keeping sensitive data outside of hackers' reach.

The Blockchain can also greatly enhance security within the *data vault* infrastructure itself. Data vault models such as those developed by Oracle rely on the dynamic management of database access privileges. But decisions to review, revoke and grant access, as well as changes to each privileged user's modes of authentication, need to be auditable without giving away the underlying information. When combined with privacy-enhancing tools such as homomorphic or zero-proof encryption, the Blockchain's time-stamped, immutable sequence of ledger entries can create an automatic, unbreakable audit trail. (It's also relevant to numerous other Luxembourg initiatives described below, especially within the context of *anchoring*.) This will give citizens the highest level of confidence possible that administrators of the data vault aren't abusing their power and that information residing within it can be trusted.

Getting these digital identity principles right is critical. Identity is the bedrock upon which so much else of Luxembourg's future digital economy will be based. Securely identifying the digital actors, be they human or device will be essential for any expansion of smart contracts, micropayments, programmable money and machine-to-machine transactions. These are the kinds of interactions that will give rise to smart electricity grids, smart transportation systems and the other infrastructure components of an Internet of Things ecosystem. But they must be secure from attack and protect privacy. A blockchain-based model will be a vital part of that.

2.2 Anchoring/Auditability

A key reason why the Blockchain is described as immutable or tamper-proof is because proof-of-work mining is *cumulative.* In order to persuade the network to change an old transaction on the Blockchain, a rogue actor would need to present more computational work than the ledger has benefitted from *since that transaction*. The current computing power of the Bitcoin Blockchain's network is about 15 million petaFLOPS, or 15 zettaFLOPS. The current market price of computing power, according to Wiikipedia, is $0.08 per gigaflop. If we take this estimate, it would take roughly $1.2 Trillion ($1,200,000,000,000) worth of computing power to be completely dedicated to the task of attacking the Blockchain in order to even have a chance at changing recent records. The older a record is, the more computing power it would take to change. This is a level of records integrity never before possible for digital systems -- quite probably for anything ever produced in the analog or paper worlds, either. What's more -- and importantly for Luxembourg's purposes -- it can be harnessed by those same legacy systems. Every critical existing database can be given this level of security in its past records by having administrators periodically create a SHA256 hash of their past state, and embedding that into the Blockchain. This process, which allows anyone to later compare the original set of data to this reduced hash format and prove a match to ascertain its integrity, is called ***anchoring***. Whenever a past record doesn't reconcile with the anchor, it constitutes ***indisputable proof of tampering.*** It is far more superior audit tool than any of the human-dependent tools that the big accounting firms use.

We strongly suggest that the government of Luxemburg pursue anchoring solutions to improve the integrity of all financial and government record-keeping systems. Currently, transaction fees on the Blockchain are around $0.07 per transaction. For the cost of $0.07 per day, the records of a firm or agency could be made completely immutable during the daily close. This has significant implications for financial accounting as it almost eliminates the prospect of bookkeeping fraud and makes the task of auditors far more comprehensive, efficient and less expensive.

One public database that Luxembourg could subject to blockchain anchoring is its registry of property titles and liens. This would potentially reduce disputes and thus lower transaction costs within a real estate market that, as mentioned, has prohibitively high entry costs. Another is the patents registry. Auditability and accountability to the recording of IP could help to differentiate the Luxembourg Intellectual Property Office with the *o*bjective of attracting international patent filings and the startups that generate them.

One jurisdiction that is already applying blockchain-based strategies to enhance transparency around public records is the U.S. State of Delaware.[262] Given that Delaware, like Luxembourg, is responsible for a large amount of corporate registration and licensing data due to the high number of incorporations based there, it presents a leading-edge example that bears studying. Delaware is placing public archives into a distributed ledger setting and exploring the prospect of doing the same for company registration data such as records of directors and other legal matters. And as an extension of this auditability feature, which can be enhanced for other uses of the Blockchain, the state is also creating a new class of distributed ledger share for

[262] Vigna, P. "Delaware Considers Using Blockchain Technology," May 1, 2016, *The Wall Street Journal*, http://www.wsj.com/articles/delaware-considers-using-blockchain-technology-1462145802

companies incorporated there. This is intended to allow for automatic, interoperable updating of underlying shareholder registry data, cutting back significantly on the record-keeping burden for startups and other private companies that must maintain ever- changing capital tables in preparation for public listing.

Extending these ideas further, Luxembourg could also trial the use of blockchain-based voting for specific initiatives. Just as the Blockchain prevents double-spending of currency, it can also prevent double-voting, potentially allow for seamless, digital and even smartphone-based voting systems in which the citizenry can enjoy both ease of use and a high degree of trust. An early application could apply in the private realm of shareholder votes, but trials of this voting model could also be developed for municipal budget items and even national referendums.

This auditability feature of the Blockchain can also be applied to many of Luxembourg's existing industries, as well as to the Luxembourg Financial Working Group's various projects. In an era of greater demand for transparency -- with new EU requirements for disclosing bank clients' tax records, for example -- blockchain-anchored audits will help the Grand Duchy stand out from other states as a home of responsible, accountable governance. As mentioned previously, it can help maintain trust in the proposed *data vault* and can be applied to the government's plans to expand *robo-advice* services by ensuring that investment algorithms aren't tampered with. It can also improve the integrity of the underlying data upon which Luxembourg's giant asset managers depend for the pricing of new and existing asset classes. Blockchain-based audits will also be vital to the administration of green bonds**,** a core element of the FWG's plan to finance the expansion of renewable energy and carbon-saving projects, as discussed below.

2.3 Tokenization

It is possible to issue a token on the blockchain that represents a real world security like a stock, bond, title, deed, or even a certificate of authenticity and which can be moved between accounts in that setting. In capital markets, its promise lies in real-time, seamless post-trade clearing and settlement, as well as in migrating custodial services from an expensive process of physical asset security to one of automated, software-backed security. The costs of maintaining the current, intermediary-dominated system are significant, not only in the fees paid to these institutions or the long, multi-day delays in concluding transactions but more importantly in the hundreds of billions of dollars tied up in collateral and withheld capital. Unlocking those funds will speed up transactions and release liquidity into markets that have been starved for it since the financial crisis-- as Luxembourg's asset managers know too well. Meanwhile, if property titles are validated and transferred through this means, the provenance can be proven in real-time, with a clear, immutable record of ownership, liens and other attachments. This can greatly lower the friction and costs in real estate transactions, potentially doing away with title insurance and other intermediary services, helping loosen up Luxembourg's tight property market. .

When combined with the secure, remote, automated execution of legal claims that's facilitated by *smart contracts* (see below) as well as blockchain-based auditability of source data, the significant reduction in transaction costs that tokenization allows could also foster entire new asset classes. That's because it becomes cost-effective to securitize income receivables that would otherwise be ineligible for traditional financial engineering. Examples include the revenue earned by household solar panel installations or income earned from temporary housing rentals.

These new blockchain securities will benefit greatly if there is a benchmark blockchain issue against which to price them. Here lies a significant opportunity for the Luxembourg government. It could follow the lead of the Monetary Authority of Singapore, which is responsible for issuing all Singapore Government Securities (SGS), and is now piloting a program to do so over the blockchain. (In this case, Singapore is using a private blockchain, not by tokenizing into the BItcoin Blockchain.)[263] Like Singapore, Luxembourg's fiscal situation, with debt-to-GDP of just 21%, is extremely solid - the two countries are among just thirteen AAA-rated sovereigns around the world. That puts it in a unique position to take a leading role in creating a euro-denominated benchmark blockchain security. The Finance Ministry should explore such an option, whether over a private blockchain or anchored into a public blockchain. This is important because the blockchain will likely be a feature of so many other securities that will be issued to realize Luxembourg digital aspirations, including that it become a home for creating, managing and trading green securities. Having issued the benchmark bond for these new asset classes will help cement leadership of this important new part of the capital markets.

Tokenization also raises the prospect of sovereign currency itself being embedded into the blockchain. Once euro-backed IOUs are issued into the Blockchain, payments can be transferred across this system in fiat. That could allow smaller and medium-sized financial institutions to transfer funds across borders without paying expensive fee and collateral costs to correspondent banks. Similarly, local exchange trading systems (LETS), substitute currency systems aimed at encouraging localized spending in parallel with the national legal tender economy, could also be administered in this manner. With Luxembourg interested in pursuing such options to boost the local economy -- in parallel with the financial sector's internationally driven, euro-dominant commercial activities -- this approach is worth studying. Whether it's to

[263] Based on interviews at Monetary Authority of Singapore offices in Singapore, April 19, 2016

develop a B2B credit management system like Sardinia's Sardex[264] or to nationally extend voucher systems such as Redange's "Beki,"[265] the Blockchain removes the risk that the administrator of the program manipulates balance data to allow double-spending or other abuses. What's more, the traceability and auditability of blockchain transactions could help the government unlock additional benefits from the circulation of these tokens. For example, it could allow the development of automated value-added tax collection, helping to broaden the tax base, which the European Commission staff has described as an important objective for Luxembourg.[266]

It should be noted that if there is an expansion in the use of digital currencies, be they decentralized currencies such as bitcoin or digital representations of sovereign currencies, there could be a disruptive impact on banks and therefore on economies with large banking sectors such as Luxembourg's. In fact, banks face even more significant disruption if central banks go ahead with plans to issue their own digital currencies under a distributed-ledger structure. This is being studied by the Bank of England, the People's Bank of China and the Reserve Bank of Australia. It would not be a surprise if the European Central Bank also studies the prospect, which has been a subject of discussion at Financial Stability Board-sponsored meetings to explore the monetary policy implications of blockchain technology. The significance for banks is that if individuals and companies are holdling funds simply for payments and short-term custody, a trusted digital currency option will make them less inclined to hold money in short-term bank deposits, since transactions can simply be managed wallet to wallet, bypassing the banking system. While that represents a threat to bank income, it must be viewed against the prospect for greater income from credit issuance as blockchain technology unlocks capital for new asset classes and for new customers among previously financially excluded populations. While such shifts are not imminent, Luxembourg's banking sector need to be prepared for what could be a profound realignment within the industry. In the spirit of the best defense being a strong offense, it's yet another reason to develop new opportunities to deploy capital within new asset classes such as blockchain-based tokenized securities.

[264] Posnett, E. "The Sardex Factor," *The Financial Times,* September 18, 2015. http://www.ft.com/intl/cms/s/2/cf875d9a-5be6-11e5-a28b-50226830d644.html

[265] Luxemburger Wort, "'Sold out' bank notes - Redange 'Beki' currency, a victim of its own success," Luxemburger Wort, May 7, 2015. https://www.wort.lu/en/luxembourg/sold-out-bank-notes-redange-beki-currency-a-victim-of-its-own-success-554b2aa60c88b46a8ce58ca6

[266] European Commission, "Commission Staff Working Document: Country Report Luxembourg 2016," February 26, 2016; http://ec.europa.eu/europe2020/pdf/csr2016/cr2016_luxembourg_en.pdf

2.4 Smart contracts

A smart contract refers to a piece of software describing a complex process involving tokens and participants, such as escrow, delivery vs. payment, and other common financial contracts. An interesting aspect of smart contracts is that many can be *enforced by The Blockchain itself*, instead of by a third-party institution. Smart contracts and tokenization promise to obviate entire layers of market infrastructure by having the rules that govern the relationships between issuers, owners and traders built directly into the covenants governing a blockchain. They will form a quasi-legal and automated execution layer to usher in an era of *programmable money* and open a wealth of powerful new applications to give investors greater confidence in the execution of their claims and interests.

The rising interest in Switzerland-based Ethereum, which bills itself as a decentralized platform for running smart contracts, speaks to how important this feature is becoming to the broader applicability of blockchain technology. In particular, smart-contract capability will be important to transactions within the Internet of Things. These automated transactions must be recorded in a public, decentralized blockchain that's secured through a robust, distributed consensus algorithm; the complexity of relationships between devices in an IoT ecosystem means that it's not feasible to have a centralized platform mediate the transactions. (This reflects the Ethereum platform's use in a number of IoT-related trials.)[267] As Luxembourg explores sensor-driven **"smart city"** solutions to the problematic congestion and mobility within the capital city, for example, it will need these decentralized smart contract structures to regulate the transfer of funds between vehicles and traffic management systems. In Luxembourg's finance sector, too, smart contracts will be the foundation of new derivative and insurance contracts in which payments are triggered by automated data inputs rather than adjudicated by an insurance firm or some third-party institution.

To optimize the development of this technology, education will be vital -- especially of the legal profession. An effort to translate these software code-driven contractual clauses into something that is consistent with the analog world of existing law is needed. To this end, the government is incentivized to work with bodies such as the Barreau du Luxembourg on encouraging education for the profession.

[267] Brody, P and Pureswaran, V, "Device Democracy: Saving the Future of the Internet of Things," IBM, September 2014. http://www-935.ibm.com/services/us/gbs/thoughtleadership/internetofthings/

2.5 Social Disruption

It is important to note that phasing in smart contracts and other blockchain applications within the financial and legal sectors will likely create some social upheaval in the form of job displacement. Given that Luxembourg's main business is banking, as well as its supporting infrastructure, consideration will need to be made for redirecting and re-deploying large parts of the workforce as frictionlessly and productively as possible.

One possible scenario is that many who now work in these evolving sectors can be re-deployed through Luxembourg's aggressive push to support new technology development in the entrepreneurial sector, feeding the very change that is being created in an extropic value loop.

With their accumulated financial expertise, these "new" workers might also find employment in the emerging global microfinance and microlending, which may also tie into the tokenization of assets.

2.6 Green Finance

Smart grids, smart homes and buildings, renewable energy and decentralized community-based energy governance are definitely coming. Because these will be constituted by many different transacting entities and machines -- in one, important segment of the Internet of Things -- the Blockchain will become the base infrastructure for regulating the flow of money and energy across this intricate web of relationships. It will provide a mechanism for automatically auditing and assessing the vast array of energy and environmental information flowing from these otherwise independent devices in different jurisdictions and markets, as well as market-pricing mechanisms needed to optimize resource allocation. As Vienna-based energy startup Grid Singularity is showing, the technology can be used to assess the myriad forms of data emerging out of this complex system and thus empower public electricity administrators to finely tune energy distribution at the lowest cost with minimal carbon emission.[268]

[268] Lacey, S. "The Energy Blockchain: How Bitcoin Could Be a Catalyst for the Distributed Grid," *Greentech Media,* February 26, 2016. http://www.greentechmedia.com/articles/read/the-energy-blockchain-could-bitcoin-be-a-catalyst-for-the-distributed-grid

In this field, we find bockchain technology sitting at the intersection of three aspects: green bonds, green microfinance and crowdfunding.[269] For one, blockchain-proven data can be the basis upon which bonds issued to finance environmental projects are priced, since investors will demand integrity assurances. Distributed-ledger technology will mediate the flow of information and money, which in turn will foster new, negotiable energy and finance instruments. These include contracts backed by low-scale “prosumer” generation capacity and new equity-like carbon-trading assets whose dividends are based on the environmental benefit and cost savings delivered by the underlying investment. Such investments can in turn be bundled into smart contract-managed securitizations that also depend on a blockchain to manage a decentralized securities exchange, creating opportunities for large asset management firms, as well as for individuals, to participate in microfinance and crowdfunded investments.

As the recent revelations about abuses at U.S. fintech firm Lending Club show, it won’t be enough to cut out middlemen in crowdfunding and other “peer-to-peer” lending platforms; these big public markets for this vital new infrastructure need the kind of distributed exchange systems enabled by blockchains and the device identity model. In effect, to accommodate all these new actors and asset categories, the securities industry will move toward distributed equity and bonds markets in which settlement and clearing occur in real-time, peer-to-peer over a blockchain.

Given Europe’s commitment to a continent-wide conversion to renewable energy, these new asset classes may quickly evolve into very large, liquid and more democratic markets for most sought-after investment instruments in the world. If Luxembourg leads the way, and embraces the blockchain infrastructure that will secure them, it can become a global hub for the origination, collateralization and trading of these products.

The overarching goal of these initiatives is a seamless, Europe-wide, integrated network of what are otherwise decentralized energy markets, with localized generation and consumption monetized through the sale of both contracts and power across borders. Given the public bond funding structure, the Blockchain will be essential if trust is to be instilled in the data emanating from the EU’s 28 different countries and 350 different regions, each defined by local conditions, standards and regulations. Blockchain-based smart contracts can be used to design derivatives

[269] As a supplemental note, in many ways what we now call green or climate aware financing, green finance and crowdfunding might be equally called Economic Performance Financing (EPF) through more traditional Economic Performance Bonds (EBP). In other words, and as already suggested, we need to engage in both a higher level of performance <u>and</u> climate change mitigation and adaptation practices. If we don't achieve that multiple objective, we may (or may not) achieve some environmental goals, but we may short-change the social and economic goals.

and other agreements that create synthetic, cross-border energy markets. That's because the technology's capacity for automation, disintermediation, powerful data analytics and micropayments drives transaction costs low enough that liquid markets can arise around securities whose complex structures would otherwise make them unviable for traditional finance.

Proposal 3: Extending the Boundary of the Luxembourg Solution

Building on the Luxembourg Sustainable Development Finance Platform, the Sustainable Energy Finance Model, the aggregation of key energy and other resources in ways that drive large-scale investment, and the introduction of Blockchain technology, we also suggest that Luxembourg assume TIR-scale financial leadership within the European Union. It should consider introducing a proposal or set of proposals to the 27 other Member States of the European Council as well as to the European Commission and the Committee of the Regions. The intent of these proposals would be to establish dedicated settings at the national, regional, and local level which might then issue public bonds for the transformation of their national, regional, and urban infrastructures into a digitalized, interconnected Third Industrial Revolution paradigm.

Given the critical need to begin scaling up sooner rather than later, small transborder pilot projects across the EU can be launched and evaluated in real-time with adjustments that are made to ensure their on-going and evolving success. At some point, and with initial successes in hand, financial and technical resources can be expanded to move pilot projects into the larger scale of demonstration ventures across sectors, within communities, and eventually within regions and nations.[270] This is very much in the spirit of a phased-in approach using what has been called experimental design[271], or what we might call here real-time adaptive management, to focus on achieving the multiple social, economic, and environmental objectives. With an emphasis on learning as we go, rather than a typical "ready, aim, fire" approach to problem solving, the management style should embrace an experimental

[270] As suggested by Byrne and Taminiau's description of the SEF, financing and operating costs (other than interest payments) can also be folded into the bonding capacity so that new revenues are not necessarily required. With a series of initial successes in hand, the confidence can build to ensure high quality bond ratings with funding that covers both operations and investments.

[271] The idea of experimental design is taken from Sullivan, Michael J., Fostering Innovation and Experimentation to Improve the Effectiveness of Energy Efficiency Programs. Working Paper. Sacramento, CA: California Public Utilities Commission, 2008.

mentality, but underscored again by real-time and ongoing evaluation to ensure continuous learning and improvement.[272]

At the same time, there is a very real need to promote the regulatory and policy elements that will incentivize appropriate and credible ESCO development, certify proper training and performance, guarantee early adoption with the transformation of all government and public buildings into Internet of Things nodes, and provide government-supported training for thousands of semi-skilled, skilled, and professional workers that will be needed to transition the building stock into nodal Internet of Things platforms interconnecting in regions across the 28 Member States. There is a need for high quality technical proposals, regulatory proposals, public policy proposals, financial proposals, new business models and business proposals, and concrete projects and other initiatives that reflect the collective judgement as to how best to foster the goals, deliverables, and initiatives set forth by the Luxembourg working group to transform the economy into a Third Industrial Revolution paradigm shift.

Proposal 4: Complementary Financial Mechanisms

The core ideas that underpin the creation of the Luxembourg Sustainable Development Finance Platform, including both LuxSEF and blockchain deployment, can be accelerated by several other financial strategies. With appropriate program design and implrementation, they may enable a greater capacity to amplify the opportunity for larger-scale economic outcomes. Following the listing in the Financial Working Group inventory, the complementary financial tools are referenced and summarized briefly here to serve as a further catalyst to encourage the expansion of financial tools within Luxembourg.

4.1 Robo Advisors / Automated Advice

Robo-adviser start-ups, especially those which integrate artificial intelligence (AI) and data analytics in underserved asset management arenas are on a disruptive trajectory (see HBR Disruption Theory).[273] Their impact should not be underestimated since theircurrent main

[272] The idea of “ready, fire, aim” is taken from the 1982 best-seller by Tom Peters and Robert H. Waterman, Jr., In Search of Excellence—Lessons from America’s Best-Run Companies, HarperCollins.

[273] *HBR: “Disruption” describes a process whereby a smaller company with fewer resources is able to successfully challenge established incumbent businesses. Specifically, as incumbents focus on improving their products and services for their most demanding (and usually most profitable) customers, they exceed the needs of some segments and ignore the needs of others. Entrants that prove disruptive begin by successfully targeting those overlooked segments, gaining a foothold by delivering moresuitable functionality—frequently at a lower price. Incumbents, chasing higher profitability in more-demanding segments, tend not to respond vigorously. Entrants

target is an underserved segment of the mass affluent and emerging affluent group of individuals with liquid financial assets of €100,000 to €1,000,000. This segment is typically overlooked by private banking. Once their business model proves successful, some players will start moving upmarket and offer highly customized services to the High Net Worth Individuals (HNWI), at lower fees and potentially higher margins. At this stage, HNWI may adopt the new service and happily accept its lower fees.

However, new players will need to gain the trust of investors and to deal with complex regulatory hurdles. This constitutes an opportunity for traditional banks and asset managers that, with a strong link to their customer base, are in a unique position to offer their services such as hybrid robo-advice, which combine personal and automated advice.

The hybrid robo-advice sector is expected to grow to manage 10% of the world's investable assets by 2025, according to a Swiss research firm. MyPrivateBanking estimates that the so-called hybrid robo-advisers will manage $16.3 trillion (€14.7 trillion) within the next 15 years, a process that could also reduce the cost of advice.[13]

The robo-advice industry is experiencing strong growth across Europe, wealth managers creating their own platforms or partnering up and acquiring specialised start-ups. Luxembourg can leverage its local expertise, ICT infrastructure and regulations to attract robo-adviser start-ups and the robo-adviser units of traditional wealth managers. One positive step forward is to create a center of expertise for AI and data analytics applied to asset management. For example, specific courses might be set up at the University of Luxembourg as a first step to attract and develop local talents. Niche markets might be established which focus on TIR-like projects to attract venture capital and develop an ecosystem of startups that are focused on TIR-specific applications of AI in the development of automated advice and process automation, perhaps with a specific cluster from Luxinnovation. Other more extended strategies should also be encouraged.

4.2 A Secure "Data Vault" as a Precondition to Smart Contracts

The Working Group is proposing to "Build a national secure data vault to drive efficiency and to become the leader in the design and implementation of smart contracts." Luxembourg should strive to set up a central, national platform where citizens and companies may upload any of their personal data (name, address, property data, electronic medical data etc.); a sort of "e-

then move upmarket, delivering the performance that incumbents' mainstream customers require, while preserving the advantages that drove their early success. When mainstream customers start adopting the entrants' offerings in volume, disruption has occurred. https://hbr.org/2015/12/what-is-disruptive-innovation safe" hosting the data and giving the citizen or the company the possibility to grant access to specific parts of this "vault" to selected stakeholders (e.g. government, banks, insurance companies, medical suppliers, etc.).

Data would only have to be uploaded once and changes could be made centrally, automatically updating contractual relations for these specific areas in the vault for which stakeholder access is granted. The deployment of such a centralized secure data vault seems to be a precondition for a nationwide roll-out of "smarts contracts" in the financial sector and beyond.

A roll-out of such an ambitious project would imply:

- Identifying and defining a first viable proof of concept
- Providing the technical, secured environment,
- Considering a secured interaction between smart contracts and big data related concepts

4.3 B2C Regional Currency

The FWG is exploring ways to "Support the deployment of B2C regional currencies in Luxembourg." Luxembourg might investigate the necessary financial and legal mechanisms that allow and enable municipalities to accept payments in regional currency. This can be further supported by generating additional research and consultations to extend that capacity.

So far, practically every real economy transaction is depending on the smooth functioning of one single currency. This "monoculture" may be very efficient, but not necessarily always resilient. New currencies could increase the resilience of the economy.

Regional currencies favor regional exchange. Beyond the effects related to this, they also have impacts directly related to the TIR process:

- Encourage the use of regional renewable resources for energy production
- Encourage the re-use of material in the region, hereby encouraging the use of reusable materials, thus encouraging circular economy
- Support regional production of food, by creating regional demand ("interlinkages")

Regional currencies can be used to test TIR-related financial innovations such as blockchain on a small scale meaning low risk, low costs and quickly feasible. Testing a "crypto beki"[274] quickly would help to give rise to an adequate tool that could be used for the implementation of other

[274] Beki is the name of an established Luxembourg complementary currency. See: http://www.beki.lu/. In January 2013, the association "De Kär" launched the only existing complementary regional currency in Luxembourg, the so-called Beki. The Beki plays a key role in creating a regional and sustainable ecosystem.

regional currencies.

Banks could offer credits in regional currencies with lower interest rates and earn the same margin than with higher interest rates. This supports sustainable development. Regional currencies enable the linkage of social outcomes to financial ones. They can enforce regional deployment of products by binding purchasing power to the regional economy and enable a self-sufficient sustainable development / circular regional economy. Regional deployment of products shortens transportation routes, reduces CO2 emissions, brings producers and consumers closer together and enables social cohesion.

Regional currencies create sensitivity of consumers towards regional production and consumption. They help creating positive feedback loops of regional exchange. Regional currencies create cooperation networks amongst companies and offer new companies access to a network of cooperating companies. They tend to circulate faster and can have a positive impact on turnover. (Demurrage increases this effect).

All these effects increase the resilience of the companies and the entire ecosystem and help increase turnover which both could have positive effects on jobs. Another socio-economic effect would be that regional currencies create more cooperation between the companies of the networks. Regional currencies can offer new business models for banks, based on exchange fee charged to convert into standard currency and/or demurrage.

4.4 B2B Complementary Currency

In April 2015, NSNBC International asked the question “Is it time for the rise of local currencies?”[275] The question is highly consistent with the FWG recommendation to “create a complementary B2B-focused currency for Luxembourg and / or the Greater Region based on mutual credit” analogous to WIR in Switzerland, SoNantes in France, and Sardex in Sardinia. “Mutual credit” means that when a transaction is made between two companies, one “goes negative” and the other “goes equally positive” on a central balance sheet managed by the mutual credit organization. These “negative” and “positive” balances are the complementary money. All “negatives” and “positives” equal zero. This system creates money at the moment of the transaction, meaning that it facilitates exchange for companies in lack of liquidity or helps saving standard currency.

The system may be limited to companies working on TIR-related projects or better conditions could be offered to such companies and organizations. It can be combined with a credit system

[275] See: http://nsnbc.me/2015/04/14/is-it-time-for-the-rise-of-local-currencies/

based on securities. Especially when a demurrage is included in the system, credits can be offered at lower interest rates, making sustainable projects profitable.

Mutual credit tends to work in an anti-cyclical fashion in relation to the standard currency, hereby helping to stabilize the economy. Due to its small area of circulation, it has similar effects as regional currencies. Mutual credit helps to increase the resilience of the economy by offering a further monetary option, which can be essential in times of credit crunch. It creates a cooperation network between companies.

A sufficient money supply is essential for a smooth running of the economy. There can be several reasons why the Euro system sometimes does not allow an adequate supply. One reason could be that the economic growth is lower than the liquidity premium. This can lead to a credit crunch.

Just as any payment can create a chain reaction of further payments, any lack of money can equally create a negative feedback loop. Thus a payment default, for whatever reason, can create a negative chain reaction downstream. This is why, in order to keep the economy running, it can be very important to have a secondary currency based on another mode of operation. This is why this secondary currency can help stabilize the economy and jobs. It can allow investments in TIR related projects such as renewable energies, by offering credits at lower interest rates, making these projects more profitable. This helps the creation of companies and jobs.

4.5 Crowdfunding

Peer-to-peer (P2P) lending provides more flexibility to the customer: Crowdfunding and other participative platforms could replace some of conventional banking functions for borrowers and lenders. Crowdfunding and traditional banking could become complementary rather than mutually exclusive models. Some platforms extract additional information to complement standard credit profiles. Crowdfunding and traditional finance could work in tandem to effect first major changes within SME's, project finance or start-ups (seed capital); in a second stage, they could be developed/used to fuel investment banking activities in a P2P fashion (It would be interesting for the Lux AIF's industry). Crowdfunding could facilitate investment in TIR projects.

4.6 Microfinance

Luxembourg is the leading financial centre for domiciling microfinance investment funds. Coupled with other financial opportunities it makes, the Fiance Working Group suggests promoting microfinance for micro-and social entrepreneurs in Luxembourg by fostering "bottom-up innovative and sustainable projects." While still a niche financial mechanism, microfinance offers Luxembourg concrete opportunities for financing projects in the framework of the Third Industrial Revolution. Especially social start-ups offer innovative solutions within the sharing economy and are based on business models that have positive social and environmental impacts. In the context of tighter lending policies and regulation, micro- and social entrepreneurs can be excluded from the regular credit system. Microfinance as smart money, combining financial support with training, coaching and mentoring contributes to the financing of the TIR.

In Luxembourg, two microfinance programs exist so far, a foundation that can be used to build upon further:

- The "Coup de Pouce" program of FUSE (Fondation des Universitaires en Sciences Economiques[276]) is an interest-free microcredit up to EUR 5.000 for young entrepreneurs.
- Microlux, a joint partnership between ADA[277], ADIE[278], EIF[279] and BGL BNP Paribas[280] is the first microfinance institution for Luxembourg and the Greater Region. Implemented in 2016, Microlux grants micro credits up to EUR 15,000 for business creation, "micro+" up to 20,000 for business development and loans up to EUR 25,000 for social enterprises. A network of experienced volunteers from the Luxembourgish ecosystem accompanies and coaches microlux clients.

Microfinance is facilitating investment in TIR projects. Based on the model of other microfinance institutions, such as Qredits in the Netherlands, microStart in Belgium, Adie in France and PerMicro in Italy, microlux is expected to boost micro- and social entrepreneurship, lower unemployment and improve job sustainability.

Proposal 5: Building a Strategic Effort

To be successful, the above-described financial mechanisms need to be accompanied by a wholesale transformation in Luxembourg's approach to financial education and regulatory policies.

[276] See: http://eco.lu/Lancement-officiel-de-la-2e-vague.%2023%20http:/
[277] See: http://www.ada-microfinance.org/en.
[278] See: http://www.adie.org/.
[279] See: http://www.eif.org/.
[280] See: https://www.bgl.lu/en/bank/homepage.htm

5.1 Financial Education

"Financial education: for an improvement at all levels".

At a time when financial decisions become increasingly significant in the lives of citizens, financial education (financial literacy) becomes essential. Against this backdrop, a growing number of countries have recently developed national strategies for financial literacy; a subject matter which forms an integral part of the border topic of "economic education", which aims to give citizens and professionals the key to understand and apprehend the economic and financial world we live. Compared to other countries, Luxembourg appears to lag behind in terms of financial education, although some players, often private, already offer financial literacy educational modules to schools and/or the broader public. Luxembourg has not yet adopted a true national strategy for financial education, nor has it officially designated a competent authority in this field. There is also little research carried-out in this area.

The three vertical pillars of the Finance WG (IoT as game changer, new business models, and the financial sector as an enabler) cannot be treated in silos. Initiatives already exist in the three verticals. However, the level of development varies from one sector to another. This has to be addressed:

- For students: existing educational program need to include more focus on financial literacy and financial education
- For teachers: exchange and information programs may need to be developed
- For consumers: exchange and information programs may need to be developed
- For professionals: specific programs should be included in conferences on the relevant changes needed in financial education

At regulatory level, technologies departments have to be established or further developed.

Action at the level of financial education should commence as soon as possible. Regarding secondary schooling, Luxembourg is currently preparing a comprehensive secondary education reform bill. Ideally, financial and economic education should be ambitiously integrated within the focus of this reform.

The overall aim should be the creation of a well-functioning ecosystem where all the actors easily interact. The main priorities include:

- The strengths and weaknesses of the Luxembourg population in the field of financial education should be identified via an ambitious assessment study (e.g. there is a specific module on financial education within the OECD PISA program that could be used as a baseline),

- A long-term national strategy in the field of financial education should be defined and implemented,
- Financial education should be included into the general school curricula.

For consumers and professionals dedicated actions plans should also be rolled out. Dedicated working groups should be created, implicating all relevant public and private stakeholder.

Luxembourg should strive to allow for a smooth interaction between the development of its financial centre, on the one hand, and training and education of local resources, on the other hand.

The main objectives in this field are twofold:

- to inform, encourage and motivate young people to experience entrepreneurship and to look for opportunities in engaging studies in the domain of new, actual and future financial instruments (ex. FinTech).
- In the short term (2016) the holding of one or several meetings between professional decision-makers of the financial sector and teachers to exchange on actual and future topics/instruments and issues in the domain of FinTech and their impact on the Luxembourg Financial Sector could be envisaged.

5.2 Regulatory Framework Review and Adjustment

There is a clear role for the Luxembourg financial community as a first mover in a changing European environment. Banks will indeed remain key actors but new actors emerge alongside banks. If these new actors are providing financial services, they will have to be regulated just like any other financial actor and under the same conditions. This is what is currently happening in Luxembourg, allowing for a level playing field between “traditional” and “new” actors.

Thus, the following considerations, even though if centered in the narrative on “banks”, have to be read and interpreted as to allow for interoperability and standardization between the different sectors in order to ensure that digitalization will be able to deploy its full benefits whilst continuing to cater for a level playing field.

If we want to have a well-functioning market implementing the new technologies, digitalization and FinTech have to be considered in a global context, with regard to the actors and the services concerned. For instance, FinTech actors will face similar privacy issues as BioTech/BioHealth actors, hence a common working structure should be put in place in order to solve data privacy aspects together with the CNPD.

We could anticipate in this context e.g.:

- The new regulation on data protection, AML 4,
- The ICT standardization,
- The Digitalisation of the EU single Market,
- Mifid II and the new financial instruments

Luxembourg should strive to anticipate the EU regulatory framework and to identify the advantages for the country included therein, in order to be a first mover within an EU regulatory framework.

Luxembourg stakeholders encourage the TIR-team of experts to provide further advice and guidance on how to reach this objective, e.g by creating specialized task forces mandated to study upcoming EU regulation in order to develop a strategy on the implementation process.

The digital transformation in financial services requires a fast paced regulatory adjustment by EU policymakers in order to enable financial innovation for the benefit of consumers and the EU economy in a fast-moving global context:

- All sectors, not least banking, are being transformed by the new digital environment and related innovative business models.
- Banks are already leading **actors in this transformation** and they contribute in many ways to the new digital ecosystem, in particular through payments and digital banking.
- Furthermore, they have embraced the digital innovation opportunity in many ways, accelerating the rethinking of their traditional business model, proposing innovative products/apps, engaging in FinTech partnerships, and financing innovative starts-ups.
- In this sense, the new digital environment represents a great opportunity to develop further financial services and bring the banking industry up to an even higher level of performance to the benefit of its users.
    - Note: Insurance and reinsurance companies are, next to banks, active players in this field. Digitalization means a direct link between the client and the company, not only to subscribe contracts but also to manage them actively, in particular in case of a claim.
    - In addition, (re)insurance companies are not only involved in the "digitalization" because they make use of technology, but also because they (partly) cover the underlying risks.
- Given this, as well as their prominent role of financing the economy (including the digital economy), banks welcome an opportunity to act as a **strategic partner for building a successful digital single market within the European Union**.

- This said, **the current regulatory framework** is not properly adapted to the deployment of digital financial services and needs further adjustments to be fit for the digital reality. Currently, the regulatory framework does not allow banks to take full advantage of technological innovations, hindering the digital transformation of the industry and obstructing the launch of innovative products and services.
- Policymakers should ensure that EU regulation is adjusted to the digital reality also for financial services. **The focus needs to be on regulating activities** rather than institutions that offer them. It is not a call for new regulations **but more about adjusting, simplifying, removing obstacles and inconsistencies and modernizing the EU regulatory framework**.
- With this in mind, the Digital Single Market Strategy (DSM) – though to be generally welcomed – should be reflected upon further, in order to take into account the abovementioned aspects.

5.3 Holistic and Consistent Deployment of Regulation

Digital transformation should be understood as a whole, seeking the right balance between the drivers of change and the impact on the existing business model.

The current banking regulatory environment does not reflect the fast moving digital phenomenon. New access methods fostering a real cross-border and cross-sector economy (e-ID, e-signature, e-invoicing, online platforms etc.) may change the way business operates across different markets. This complete shift of paradigm requires a renewed approach in order to efficiently balance benefits, risks and avoid market distortions. It means that banking legislation should be adapted to the digital market reality.

- **Overall, the Digital Single Market strategy should consider and be aligned with existing or forthcoming EU initiatives which will affect financial services.**

It should notably be the case regarding the work currently conducted by the European Commission to build a Capital Markets Union (e.g. alternative –digital- investment platforms for crowdfunding, Venture Capital) or on the Green Paper on Retail Financial Services (e.g. digital cross-border sales in Europe). Some recent or on-going EU legislations do not yet properly or fully address the development made possible by digitalization, leading to certain contradictions or inconsistencies that are potential obstacles to the Digital Single Market becoming a reality. It is notably the case for the Payment Services Directive (PSD2), the General Data Protection Regulation (GDPR), the Network and Information Security Directive (NIS) or the 4th Anti-Money Laundering Directive. Also, for instance, most EU regulators enforce cloud technology to be compliant with local outsourcing regulations (outsourcing regulations have not been harmonized) which by definition is against the idea of the cloud (which is meant for cross-border). These regulations can contradict with the core objectives principles of the cloud or lead to further inconsistencies.

5.4 Avoiding Fragmentation of Regulations

Currently the national consumer protection and contract laws differ throughout the 28 Member States and companies usually need to act in accordance with the host countries' national consumer protection laws and supervisory measures. It is also true that the retail financial services market is still fragmented due to culture/language barriers, divergences in national taxation, civil law and product specifications defined by national regulations and consumer needs which remain mainly local.

At present, inconsistent requirements in different countries are hampering innovation in new services. Banks and consumers are not able to reap the full benefits of digitalization. This is particularly the case regarding access to platforms, data privacy, cloud and big data.

5.5 Ensure the Right Conditions for Innovation to Thrive

- **Banks should be allowed to develop activities beyond traditional banking under the same conditions as their competitors.**

  Considering the overall picture of how financial services are provided in the digital arena, it is key to provide the right environment for banks to innovate.Banks planning to develop activities beyond pure traditional banking (marketplaces, aggregators) or potentially integrating FinTech companies into their business models, should not be constrained by the obligation to consolidate any subsidiary or affiliated company within the regulatory scope of the parent company owing to capital requirements, level of supervision, security and liability.

- **The principle of "same services/risks, same rules" should apply to all companies regardless of the sector or location.**

  A competitive and innovative EU Digital Single Market features safeguards regarding consumer protection, trust and security. Fair trade and open competition on the market enables consumers to access a range of new competitive products with higher performance. It also enables companies to offer products to a broader array of customers. To do so, the right competitive environment should be set and allow an open and fair competition among the market players.

  - **Regardless of the sector:** Because products and services will be under high pressure to be supplied instantly, safely and with a guarantee of quality, the principle of "same services/risks, same rules" should apply to all companies offering similar products and services whatever the market/sector they are targeting when it involves comparable risks. All companies should benefit from the same opportunities and flexibility to innovate.

- **Regardless of the location (the global dimension should be considered):** because the DSM should have a global dimension, it is also important to eliminate or reduce the regulatory divergence with other non-EU countries such as the United States, Asian countries etc.
  - For example, regarding accounting rules for intangible assets, there are different treatments between the EU and US concerning capital requirements/consumption for investment in software. In accordance with the International Financial Reporting Standards (IFRS) software should be accounted as intangible assets and, as such, deducted from the "core capital" of banks, while according to US Generally accepted accounting principles (GAAP) accounting standards, software is considered a tangible asset as "plant, properties and equipment" and hence not deducted from core capital. This creates a competitive distortion between EU and USA banks.
  - On data protection and data value chain: an uneven international playing field in the storage of data via cloud computing can be observed. EU players face certain geo-localisation and data privacy restrictions whereas US players do not and are able to use data stored on the cloud all over the world. There are also restrictions to the development of new digital business models in the cloud, with a worldwide architecture, based on the exploitation of data

All companies offering similar financial products and services involving comparable risks, whatever the market/sector they are targeting, should be submitted to the same rules (e.g. AML/KYC) or offered the same flexibility as their competitors (e.g. prudential and compliance). The Digital Single Market should insure a level playing field in the application of such measures.

- **EU policymakers should assess the opportunity of developing in Europe a regulatory framework for experimentation such as e.g. regulatory sandboxes that would be open to all innovative players.** Given the huge potential for transformation, policymakers should be encouraged to investigate new ways of providing regulatory flexibility testing innovative products, services, business models and delivery mechanisms without immediately incurring all the normal regulatory consequences of pilot activities, while at the same time providing sufficient safeguards to consumers. Eligibility criteria would need to be the same for all, both incumbents and new players.

5.6 Understanding and Respecting Basic Balances

New customer centric models demand a broader and more comprehensive clarification of customer protection rules, the role to be performed and liabilities to be borne by new business models. If this point is considered, customers will be able to enjoy much better protection in relation to their funds and their purchases as well as to their privacy and ability to interoperate; The regulatory framework should properly balance the promotion of new digital value propositions while ensuring appropriate consumer and investor protection, data privacy, security and prudent risk management.

- In addition, **strengthening cooperation and raising the awareness of EU citizens on the growing threats from cybercrime is crucial**. Financial institutions are one of the primary targets for cyber-attacks. As a result, the industry is committing considerable IT investments towards protective measures for customers and to maintain trust. These protective measures should also encompass more initiatives to increase the awareness of the employees in the financial sector. Making digital finance secure and building trust should be a concern for all, including public and private actors.

  It notably implies the establishment of a legal framework and creation of a Joint Public/Private Cybersecurity Platform:
  - To exchange information about latest risks and trends.
  - To exchange best practices in cyber-crime prevention.
  - To disseminate the awareness about the cyber risks among the industry peers and the public.

Certainly, the (re)insurance sector has an important role to play for increasing the understanding of the cyber threats, as it covers the risks for now several years. If initially the covers were restricted to the costs associated to the appointment of IT specialists to deal with the incident, the covers embed now loss of data and liability. This means that the (re)insurance sectors has gained experience in preventing the incidents, understanding the origins and restricting the consequences. This experience should be leveraged.

At the same time, banks are facing increasing information and incident reporting requests from various authorities (SSM, ENISA, national competent authorities, etc.). A coordinated and more harmonized approach between various authorities would optimize banks efforts in this field.

Ultimately a clear harmonized legal framework regarding incident information sharing between companies should be put in place. Concrete actions are urgently needed at the European level. These actions should be supported by the Luxembourg Government as almost any piece of Luxembourg legislation is derived from EU regulatory framework.

INFO BOX – 10 THEMES TO BE ADDRESSED FOR A SUCCESSFUL DIGITAL TRANSFORMATION

1. General legislation and regulation of the financial sector: Transformational change requires intense cooperation between industry, lawmakers and regulators. Regulators will play a key role to ensure a level playing field as well as protection. Success can only be granted within the European Digital Single Market (striking the right balance between enabling innovations, ensuring stability, protecting consumers, and preventing financial crimes as well as avoiding market fragmentation) and beyond.

2. Cloud: Create an appropriate framework (including by promoting ICT standards) that allows EU financial services to innovate by using cloud technologies taking into account the international dimension. Ensure level playing field among European (compliance with local outsourcing regulations…) and non-European actors (e.g. data location restrictions)

3. Data (data value chain and privacy): Ensure legal certainty on the use of Big Data and open data and a common understanding on key concepts such as data ownership and anonymisation and pseudo-anonymisation. Provide for an appropriate regulatory framework (including assessing further the impact of the recent data protection regulation on digital banking) which ensure a fair access to (open) data, and allows for the development of competitive business models based on data, as well as a comprehensive use of data analytics while ensuring safeness and privacy of personal data within the EU and:
   - Allowing balanced restrictions on profiling (notably for a full use of data analytics to the benefits of customers, as well as e.g. in the assessment of creditworthiness and fraud prevention);
   - Considering the international dimension by promoting consistency between EU rules and rules applicable to non-European actors;
   - Allowing a wider range of (pseudo-) anonymised data processing for client's personal data.

4. Platform and infrastructures: Regulate digital platforms and infrastructures to ensure a high level of security (including strong authentication) and a balance rights and liabilities of third party providers. Regulate access on a reciprocal basis for financial institutions to customer related information held in other digital platforms.

5. Access/e-identification/e-signature: Harmonise the rules of digital access (including customer on-boarding, authentication and KYC processes) to banking services and product, and ensure interoperability within the EU by promoting banking initiative where banks are providers of digital identity services, possibly in collaboration with public authorities ; remove existing barriers to the cross-border use of electronic identification by defining "banking assurance levels" for authentication purposes and by promoting an interoperable environment with the recognition of a preferential use of cross-border national e-IDs in agreement with public authorities; establishing common e-KYC standards for individuals and companies and common standards for document authentication and procedure to ease the use of e-signature at domestic and cross-borders level.

6. Payments and aggregation: Establish harmonized licenses, conditions of approval and supervision across EU to operate with transactions, payments and financing and foster the viability of European card and payments business models. Make sure that the same level of consumer protection and data privacy is implemented by all the actors in the payment and aggregation chain. Ensure a fair allocation of rights and liabilities amongst all actors in the payment/aggregation chain.

7. Cybersecurity: Ensure high standards of cyber protection requirements for entities and third party providers accessing platforms and bank accounts. Avoid duplicative reporting requirements. Raise awareness towards public authorities, industry and consumers on potential cyber risks & threats. Create the appropriate framework and network for information sharing (threats, incidents ad countermeasures)

8. Blockchain technologies: For the financial services sector Blockchain technology could provide opportunities to overhaul existing banking infrastructure, speed settlements and streamline stock exchanges; EU framework (although perhaps premature to consider any regulation at this stage) should put the banking sector in the position to take full advantage of solutions using this technology.

9. Alternative lending and investments (assets and liabilities): Ensure consistent harmonization and supervision of investment and lending licenses to ensure customer and investor protection; Ensure a level playing field among EU players and with non EU players, remove inconsistencies in EU legislation and obstacle to innovations.

10. Digital skills: Improve employee's skills and competencies focusing on the conduct of a digital/online business in order to guide customers through online product and services. Improve job rotation practice, to help incentives for knowledge exchange and to build multi-skill professional profiles (e.g. through structured job rotation).

SMART ECONOMY

OVERVIEW

Co-Chairs Claude Strasser and Mario Grotz, and the Luxembourg Smart Economy Working Group;

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Luxembourg already ranks number one in Internet penetration in the European Union, with 100% coverage. 99.4% of households have mobile phones and 94% of all households have computers. Eight out of every ten households have high speed access. In addition, 9 out of 10 businesses use broadband connection.[281]

Luxembourg also boasts a highly advanced ICT sector which accounts for 6.6% of the total gross added value of the country. The ICT sector accounts for 4% of employment in Luxembourg. Moreover, Luxembourg hosts some of the leading ICT companies including Amazon, Ebay, Vodafone, and Rakuten.[282]

These numbers constitute an important starting point for the continuous build-up of a growing ICT infrastructure in Luxembourg that must be able to sustain the exponential traffic growth rates foreseen in the future. For example, world mobile data traffic is expected to grow to 30.6 exabytes per month by 2020.[283]

Tim Berners-Lee put the World Wide Web online in 1990. Today, a younger generation is studying in global classrooms via Skype and FaceTime, socializing with cohorts around the world on Facebook, gossiping with hundreds of millions of peers on Twitter, sharing photos on Snapchat, contributing to the knowledge of the world on Wikipedia, tapping into virtually all of the information generated in the world on Google, and taking free Massive Open Online College Courses and receiving credits.

The World Wide Web is simple in design and acute in impact. The Web allows anyone, anytime, anywhere, to share information with anyone else, without having to ask permission or pay a royalty fee. The Web is designed to be open, universally accessible, and distributed.

[281] See: http://ec.europa.eu/eurostat/statistics-explained/index.php/Information_society_statistics_-_households_and_individuals
[282] See: http://ec.europa.eu/eurostat/documents/2995521/7141198/4-21012016-AP-EN.pdf
[283] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2015–2020, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.pdf

Three and a half billion people, nearly half the human population on Earth, are currently connected to the Internet. Recently, China began manufacturing $25 smart phones with more computing power than what was used to send our astronauts to the moon, increasing the prospect that soon the entire human race will be connected and communicating with one another, sharing knowledge, work, and entertainment, making new friendships and finding mates at near zero marginal cost in the largest extended fictional family in history.[284] The Communication Internet is erasing border after border and connecting the human race in a single, global, virtual public square – and the marginal cost of participating is nearly zero and virtually free.

And now, even the airwaves are becoming free. New technologies for managing communications and Big Data over the radio frequencies are changing the very nature of broadband communications. Smart antennas, dynamic spectrum access, cognitive radio technologies, and mesh networks are among the new technologies that are expanding the spectrum to a cheap and abundant resource by using it more efficiently and with greater agility. This will result in both licensed and unlicensed use of spectrum, addressing the needs for ultrabroadband access, mission critical services, and the Internet of Things with trillions of interconnected devices. Evolved WiFi and 5G networks hold the promise to fulfil these dreams.

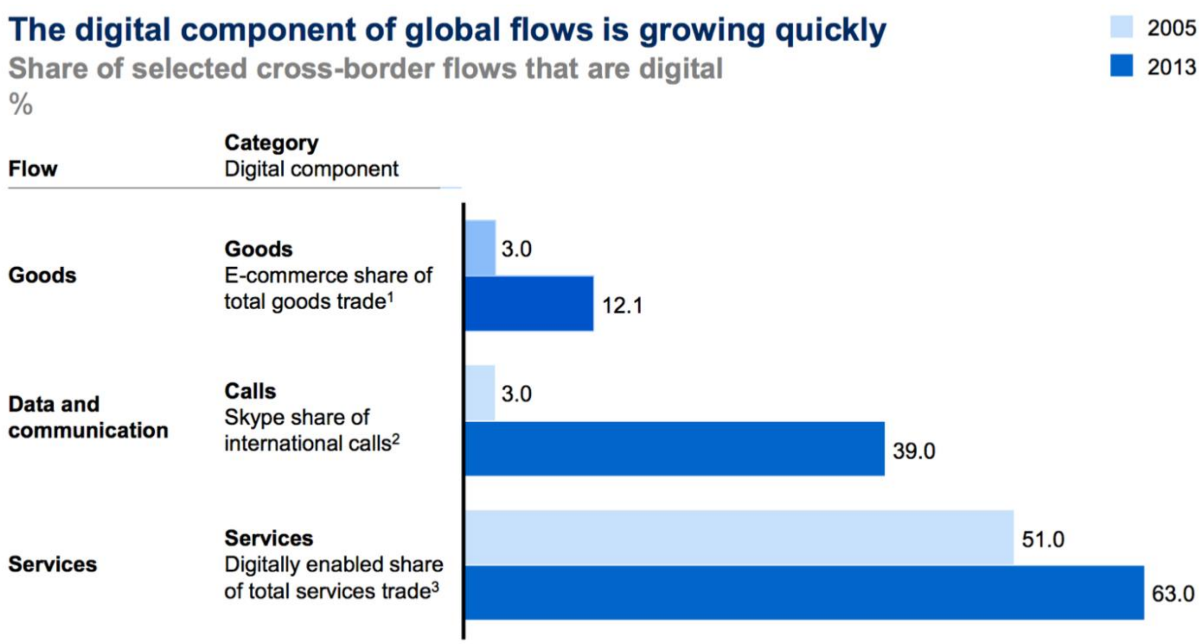
But open, transparent, and free communication is not assured. The Internet communication revolution has a dark side. Universal interconnectivity makes possible the democratization of communication and the flow of Big Data, but also poses serious challenges. How do we ensure network neutrality as well as critical services in an interconnected world? How do we prevent governments and global companies from monopolizing the Internet for political and commercial gain? How do we protect personal privacy and guarantee data security? How do we prevent cybercrime and defend against cyberterrorism in a world where everyone is connected? How do we build resiliency into the communication system to avert a massive disruption and even collapse of the platform?

The Dark Net is already ever-present, and becoming a dangerous menacing force that could forestall and even derail the journey into a more democratic, cosmopolitan, and ecologically sustainable society. Local and global efforts that keep the Communication Internet up and running and Big Data flowing freely and not subject to massive disruption will define the political struggle in the coming decades, especially in highly developed nations like Luxembourg that are far ahead in the build out and scale up of a ubiquitous communications network, and therefore more likely to be vulnerable to the forces of the Dark Net. In preparing for a Third Industrial Revolution future, Luxembourg will have to devote considerable human and financial

[284] See: http://www.wsj.com/articles/mozilla-to-sell-25-smartphones-1402466959

resources to build resiliency into every part of the communication and Big Data network that is emerging.

The dot-com bubble of the late 1990s was a misestimate of the timing, not the magnitude, of the digital revolution. Today, digital technology is replacing labor in increasingly complex tasks. This process of labor substitution and disintermediation has been underway for some time in service sectors – think of online banking, enterprise resource planning, procurement or customer relationship management. And it is spreading to the production of goods, where robots, cyberphysical systems, new sensor technology and 3D printing are displacing labor. Luxembourg and the EU are part of this global digital transition towards a world in which the most powerful global flows will be ideas, e-services and digital capital, not goods, traditional services, and traditional capital. The rapidly growing digital component of global flows exemplifies this trend[285]:



The transition into a seamless emerging Digital Era will favor regions that build the infrastructure, institutions, skills and business environments that their innovators, companies and citizens need to participate fully.

Adapting to this digital transition will require shifts in mindsets, policies, investments (especially in human capital), and increasingly also models of employment and distribution. For an agile, wealthy and advanced economy such as Luxembourg, this creates new openings to carve out

[285] Gl*obal flows in a digital age: How trade, finance, people, and data connect the world economy*, McKinsey Global Institute Report, April 2014.

profitable roles in the new digital global economy. Already a world leader in digital adoption, Luxembourg has a competitive advantage when it comes to the build out and scale up of a Third Industrial Revolution digital infrastructure.

Not surprisingly, the objectives set out in the Luxembourg national strategy far exceed those set by the Digital Agenda for Europe. "The national plan aims for networks with ultra-high-speed rates, more precisely 1 Gbps for 100% of the population in 2020. 85% of the population may already be connected at rates of 30 Mbps or higher."[286] This leads to the question **how Luxembourg can scale and monetize this competitive advantage beyond its established core ICT business.**

On the other hand, we believe that shortcomings as recently listed in the EU Commission's Country Report on Luxembourg[287] and also the World Economic Forum Networked Readiness Index[288] especially in targeted Public and Business R&D Investment (despite positive investments and reforms at the University of Luxembourg and LIST), suggest that the overall Business Environment is still lacking an Entrepreneurial Ecosystem (despite the introduction of new seed funding structures and the Fit4start program). Moreover, Luxembourg has relatively high regulatory barriers in the service sector (notably in business services and retail), is experiencing negative productivity growth, relatively high unit labor costs, below EU-average PISA students' performance, especially in mathematics and science (not to mention the universal bottleneck in computer science education), risky reliance on diminishing tax revenues from a legacy financial sector, and relatively high youth unemployment.

If properly addressed, these positives and negatives can spur a sense of urgency on the part of the Government of Luxembourg and other key stakeholders to act beyond previous initiatives and diversify Luxembourg's economy towards a truly sustainable and scalable Third Industrial Revolution. To quickly advance the new economic paradigm, Luxembourg will need to draw upon its prior success in the ICT sector and begin a rapid build out of a digitalized Renewable Energy Internet and digitalized Mobility Internet alongside its already developed Communication Internet connected by an Internet of Things platform.

Based on lessons learned from comparable second mover (in comparison to Silicon Valley) smart economy hubs such as Tel Aviv, Singapore, London, Barcelona and Zurich, we strongly believe that strength in only one aspect of a digital/smart economy (namely Luxembourg's

[286] See: https://ec.europa.eu/digital-single-market/en/country-information-luxembourg#summary-of-broadband-development-in-luxembourg

[287] *Commission Staff Working Group Document: Country Report Luxembourg 2016*, European Commission, February 2016.

[288] The Global Information Technology Report 2015: ICTs for Inclusive Growth, WEF, Cornell University, INSEAD, 2015.

outstanding digital infrastructure) is not sufficient to sustainably boost overall economic performance, tax revenue, and employment. What is needed is an interactive mix of institutions, skills, business ecosystems, regulation and infrastructure. For comparison, we point to the **good "Smart Economy" performances across the board** in Singapore[289] and Switzerland as shown in the WEF table[290] below.

Both locations faced comparable legacy financial sector models and similarly challenging policy, investment, demographics, human capital and productivity challenges as Luxembourg but managed to find their respective sustainable niches in the global digital economy.

	Political and Regulatory Environment	Business Innovation and Environment	Business Usage	Skills	Government Usage
1st	New Zealand	Singapore	Switzerland	Finland	Singapore
2nd	Singapore	United-Arab Emirates	Japan	Singapore	United-Arab Emirates
3rd	Luxembourg	Hong Kong	Sweden	Switzerland	Korea, Rep
4th	Finland	Canada	Finland	Belgium	Bahrain
5th	United Kingdom	United States	Germany	Qatar	Qatar
6th	Norway	New Zealand	Netherlands	Netherlands	Estonia
7th	Netherlands	Norway	United States	New Zealand	Japan
8th	Canada	Netherlands	Denmark	Ireland	Saudi Arabia
9th	Switzerland	United Kingdom	Israel	Canada	Malaysia
10th	Sweden	Switzerland	Norway	Germany	New Zealand

[289] Compare Singapore's focus on 3 Strategic Thrusts*, Infocomm Media 2025 Report,* Ministry for Communication ans Information Singapore, August 2015.
[290] The Global Information Technology Report 2015: ICTs for Inclusive Growth, WEF, Cornell University, INSEAD, 2015.

STATE OF PLAY AND LUXEMBOURG VISION

Based on deep collaboration between the Luxembourg Working Group and TIR Consulting Group LLC, "Smart Economy" should be approached as a de-siloed META-pillar, which brings together communication, energy, and mobility in a seamless infrastructure made up of the Communication Internet, the Renewable Energy Internet and the automated GPS and driverless Mobility Internet in a super Internet that will fundamentally change the way Luxembourg manages, powers, and moves economic activity across its myriad value chains. Moreover, this Meta-Pillar should be leveraged to define and further develop a specific core strategic vision that transcends and integrates not only the five Smart Economy themes proposed by the Luxembourg Smart Economy Working Group but also the other sub-pillars in the evolving Luxembourg Third Industrial Revolution Strategy Study.

According to Townsend and Lorimer, digital masterplans are most successful when they aspire to be visionary.[291] Vision, in this context, is understood not so much as a detailed blueprint but as an overarching theme that enables an effective implementation of the masterplan over time and across changing stakeholders and public-private partnerships (governments, CEOs and change of transition team leaders).

Luxembourg has considerable assets and knowhow when it comes to broadband, WiFi and specialized Telecom infrastructure, FinTech, EU-regulatory leverage through local EU institutions and offices, legacy in registration and incorporation of legal private and business entities for global customers, taxation and accounting know-how, scaled "trust economy," and several small scale e-Administration pilot projects.

Recognizing the value of data flows, many locations are trying to create the "next Silicon Valley." But innovation is notoriously hard to orchestrate—and that is not the only way to participate in the digital global economy. "Our experience shows that countries benefit from receiving cross-border digital flows as well as producing them. In other words, countries do not need to transform themselves into digital content or platform producers to benefit from global data flows."[292]

It is therefore our advice to formulate one core strategic vision that builds upon Luxembourg's existing assets as described above, positioning Luxembourg both as a producer and as a

[291] Digital Master Planning: *An Emerging Strategic Practice in Global Cities*, NYU Marron Institute of Urban Management, June 2015.

[292] http://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Digital%20globalization%20The%20new%20era%20of%20global%20flows/MGI-Digital-globalization-Full-report.ashx

recipient of digital flows, and develop these strands further into an overarching theme that can position Luxembourg as a leader in the journey to a smart Digital Europe.

The "digitized Internet of Things Economy" will inevitably have a deep impact on the way we live, work, and relate to each other. In this interconnected world, data is the new oil that fuels the economy and a smart use of data will be the most valuable asset to stay ahead of competition in terms of innovation, client retention, efficiency and productivity. ICT is clearly the enabler to free the economic potential across all the critical sectors that make up the Luxembourg commercial space. The Luxembourg working group nevertheless shares the view that while a "digital economy" is at the heart of a "smart economy," other elements need to be taken into consideration to reap the full benefits of this transformational process. The working group has built its report around the following building blocks:

- What is the vision for a "Smart Economy" and, more importantly, what should it achieve in terms of broader societal goals;
- What is the current positioning of Luxembourg in the digital economy (SWOT analysis);
- What is the roadmap to achieve a "Smart Economy" in Luxembourg and what are the key topics to focus on.

The Smart Economy should reconcile quantitative and qualitative growth targets to allow Luxembourg to maintain its high living standard while dramatically lowering the marginal cost of producing and distributing goods and services. With this in mind, Luxembourg has prioritized three overriding long-term goals:

- Competitiveness and efficient use of resources
- Digital Inclusion, "Buy in" by society at large
- Sustainable growth and social welfare model

In the past decades Luxembourg has created exceptional wealth for the country, building on the strengths of its open and export driven economy. This growth model is nevertheless not sustainable in the longer term without a smart approach towards economic and societal developments. Indeed, the current growth model poses serious drawbacks for the country (example: financing social security and pensions, environmental impacts, increasing workforce and population, dependency on financial sector, etc.) and for its neighboring countries (example: the flight of skilled workforce and fiscal resources). Luxembourg also has to cope with a changing international environment, particularly in regard to regulations and taxation issues where international institutions undermine the sovereignty rights of national governments.

The smart economy concept reconciles the economy with the principles of sustainability through the use of ICT for inclusive growth, economic diversification and social empowerment. ICT is used to enhance quality, performance and interactivity of services, to reduce fixed costs, decrease ecological footprint, and improve connectivity between users.

Smart economy development, through the increasing use of the Internet of Things (IoT platform), generates a high quantity of data requiring an extensive infrastructure, resilient information highways, data centers, as well as high-performing computing power, allowing real-time exploitation of data.

Innovation is the key to a smart interconnected economy: new ideas help to generate economic activity as well as to attract new businesses and new workers. The Internet of Things society fosters deep collaboration in ever-expanding webs, enabling traditional industries and new start-up entrepreneurial enterprises to transition from the conventional adversarial relations in traditional markets to shared open-source relations on a burgeoning commons. Working collaboratively to solve problems and create new opportunities is crucial to a thriving smart economy. Through connectivity, the collaboration models are redefined.

Digital technologies play a central role in value creation in the economy and bring a radical transformation to research and development and to the production and distribution of goods and services. Areas like Big Data, the Internet of Things, and automatization processes offer great opportunities for every sector and industry.

Luxembourg’s Smart Economy working group has identified four critical areas that underline its current strengths and weaknesses:

- State of the art ICT infrastructure; Luxembourg is well-positioned according to latest statistics.
- Business' integration of digital technologies; Luxembourg is weak compared to the EU average, especially as regards SME’s.
- ICT Skills; Luxembourg lacks the expertise to deploy the digital revolution and the educational system is not positioned to overcome the digital skills gap.
- Framework conditions that stimulate the uptake of new technologies; Luxembourg is generally perceived as “business friendly” but room for manoeuvre is shrinking and competition is strong.

Strengths	Weaknesses
International infrastructures :	Small country – no critical mass
Connectivity – golden ring	Market structure – a few large players dominate
RTT latency values	No single EU market
Internet exchange point	Applied R&D not well developed
Data centres :	ICT skills underdeveloped
99.995% availability	Limited ICT education
13% of the world's Tier IV capacity	Limited use and availability of renewable energy
Redundancy, security, trust	Limited venture capital available
Nationwide fibre networks	Risk averse Mind-set and Culture
Competitive price for electricity	High salary costs
PSF Status	
PSDC Status, law on e-archiving	
Law on "cloud computing"	
Strict application of data protection regulations	
Financial sector as main driver of the economy and ICT usage	
Simple access to authorities and political decisions makers	
High GDP and salaries	
Multilingual workforce	

Opportunities	Threats
Development of specialist functional skills to service large ICT suppliers or their customers.	Failure to invest in infrastructure on a constant basis
Development of advanced networking solutions and intelligent networks, social network computing and GPS applications.	Competing in a local market where international brands are most trusted
Providing advanced capability in data storage, data processing, data mining and knowledge extraction for any organization in the world but in particular locally.	Competing on a world wide scale
Attraction multinational investment	Innovating and producing in fragmented markets
Position Luxembourg as secure, trusted HUB	Intensive Competition from neighbouring countries
Redundant electricity grid	New VAT and tax regimes
Cyber security	EU and G20 pressures
Pro-active Government (Luxembourg for Business, Luxembourg for ICT)	Political pressure on international companies
Small country – innovation lab	Dependant on electricity grids of neighbours
Include the three dimensions of sustainable development	ICT workforce and skills missing
	Limited creativity
	Public awareness of cyber risks and security
	Increasing public debt, limited investment capacity

Moving towards a smart economy requires a systemic approach with clear milestones that enable the country to become a hotbed of opportunities, talent and innovation. A comprehensive strategy should focus on five mutually reinforcing pillars embedded in a coherent action plan with short and long term deliverables:

- **Smart Governance**: The objective is to identify key factors to be addressed in moving to a digital era as well as to present its findings for a change management approach to be achieved over a timeline from 2016 until 2036, with the concise goal to have a new governance model in place and running by the start of the country's bicentennial in 2039.
- **Smart People:** A smart economy will be based on a society which embraces underlying technological changes. Emphasis will need to be placed on digital inclusion, new managerial/organizational skills that are required to compete in the digital age, education and lifelong learning, and fostering new talents and skills that anticipate changes in the labor market.
- **Smart Public R&D Spending**: Luxembourg's economic future will depend on how effectively it develops a National Innovation System. The stakeholders in the public sector, private sector, academic community, and civil society will need to establish a myriad of collaborative networks to share knowledge and best practices in the pursuit of cutting-edge R&D projects and initiatives that can effectively transition Luxembourg into a flaship Smart Economy.
- **Smart Use of Digital Technologies in Business and Society:** Disruptive business models and improved production processes, empowered by digital investments, will generate new national and international market opportunities. Luxembourg will need to fully exploit these opportunities to become a more promising place to invest and do business. Although a leader in broadband penetration, Luxembourg will need to pursue an aggressive digital master plan to encourage the integration and smart use of new technologies by businesses across all the industrial sectors.
- **Approach to Smart Regulation:** Luxembourg will need to transform its regulatory regime to accommodate the new challenges and opportunities that come with the transition from a Second to a Third Industrial Revolution economy. The digital technology revolution favors ever-expanding connectivity across political boundaries and business sectors, forcing a disruption in conventional business practices and commercial relationships. New regulations, codes, and standards will need to be put in place to encourage a more distributed, transparent, and collaborative approach to commerce and trade and the pursuit of a more sustainable ecological society.

PROPOSALS

1 Business Model Innovation

1.1 **Foster and focus applied research in the key areas of smart city, smart energy, smart space, autonomous driving, High Performance Computing, Big Data enabled applications, and FinTech.** The University of Luxembourg, LIST and other applied research stakeholders are on the right path but not yet sufficiently focused, staffed and funded to foster know-how transfer from academia to business and society through Dual-Use oriented applied research projects. The motto should be "quality, focus and excellence over quantity." Luxembourg should explore other best practices including a comparison with ETH Zurich, Fraunhofer SIT, IBM Research, the National University of Singapore and EPFL (EcolePolytechnique Federale Lausanne).

1.2 **Streamline the overall transition process by focusing on a few Lighthouse Projects/Smart specializations clustered around the E-Luxembourg core strategic vision.** Smart specialization is an innovation policy concept designed to promote the efficient and effective use of public investment in research. The goal of smart specialization is to boost regional innovation in order to achieve economic growth and prosperity, by enabling regions to focus on their strengths.

1.3 **Foster Entrepreneurship through innovative start-up ecosystems.** Consideration should be given to a Yozma-type fund, tax incentives for VC investments, the establishment of entrepreneur centers at LIST and the University of Luxembourg, and entrepreneur exchange programs with established innovation hubs in the US, EU and Asia.

1.4 **Cyber security and cyber resilience are crucial factors for building a sustainable and reliable smart economy. To provide a full spectrum of services, a clear distinction should be made between regulatory and business aspects.** Cybersecurity Regulation at the national level needs a dedicated agency, like the newly established ANSSI, in addition to an inter-departmental coordination body like the CSB. Cybersecurity for the Private Sector (Cybersecurity as a Service, CaaS) needs services provided by an organization such as "SMILE GIE." The underlying ICT of Luxembourg's smart economy needs to be resilient to malicious attacks or acts of nature. There is tremendous potential for Luxembourg to contribute to the growing global demand for cyber resilience and cyber security products and services, given that cyber security is a high-growth sector with a projected volume of

$140bn by 2024. Since cyber security and cyber awareness is crucial for a smart economy, Luxembourg might provide cyber security training courses – including online training – by focusing on the specific needs of Luxembourg and its economy. Another crucial element of Luxembourg's cybersecurity strategy is the introduction of a dedicated Cybersecurity Venture Capital fund to foster disruptive commercializations through early stage and potentially Series A/B funding.

1.5 **Develop and foster Data Analytics in Banking and Finance with a focus on innovation.** Use the synergies of related initiatives like "Luxembourg for Finance," "Digital Lëtzebuerg," "ICT Cluster" and private sector infrastructure to further develop and expand existing data centers. The European Commission's "Country Report Luxembourg 2016" states: "The financial sector represents the main economic engine of the country with a share of 27 % of total value added and 11 % of total employment in 2014. While Luxembourg's predominant business model is based on fund administration (the second largest center worldwide, after the US) and wealth management, banking and the insurance sectors are also important. Luxembourg has weathered the financial crisis relatively well, mostly due to the high degree of diversification and specialization of its financial sector." At the same time Luxembourg is strong in data centers, and especially with regards to financial institutions: "Luxembourg boasts one of the most modern data center parks in Europe and has 19 data centers in operation, with a total net floor space of over 40 000 m² (over 440 000 ft²), surpassing cities like Stockholm or Brussels with regard to shared IT Rooms. Many major public and private players have established their data centers in Luxembourg, including the European Commission and many financial institutions."[293]

1.6 **Digital Innovation Cluster for Autonomous Driving.** This innovation cluster will shape tomorrow's safe and intelligent mobility through researching and testing self-driving vehicles. For this purpose, realistic traffic scenarios will be addressed in a test field infrastructure in Luxembourg. The project will also pave the way for economic (e.g. the Sharing Economy), legal (e.g. data protection issues of autonomous driving), technological (each car is interconnected to each other, and Internet-connected to the cloud), and cybersecurity (automotive cyber security) R&D to successfully usher in autonomous driving, car-to-car, and car-to-infrastructure networking. The project will be linked to E-services such as car registration and taxation services through the E-Luxembourg portal. "Luxembourg is centrally located in the automotive heart of Europe. At the crossroads between Germany, France and Belgium, it offers 'just-in-time' access to the major

[293] Source: LUXEMBOURG and ICT: a snapshot

European car manufacturers and assembly plants. It is an ideal location for component suppliers with a multi-customer base to deliver their products easily and directly."[294] Recently, the Grand Duchy has opened an Automotive Campus: "This industrial site is dedicated to research and innovation in the automotive sector."[295]

1.7 LUX-TIR Long-Tails and Multi-Sided Platforms. Two new business models enabled by the Internet, and now the advent of the Internet-of-Things, are the so-called Long-Tail and Multi-Sided Platforms business models. Long-Tails refers to the possibility of companies efficiently aggregating a large quantity of very small market niches, each of which would have been insufficient to support a traditional business model. Overall, this aggregation potentially leads to a significant market share. On the other hand, Multi-Sided Platform businesses offer a platform that can be used by multiple customer segments that are not mutually independent. The paradigmatic example is the Google approach, where the two-sides are the Internet users on the one hand, and companies looking for advertising for their products on the other hand. The aim of the LUX-TIR Long-Tails and Multi-Sided Platforms project is to launch funding actions specifically targeted to start-up companies that are based on these business models, heavily exploiting the possibilities for value proposition, customer segmentation, distribution channels, customer care, offered by the Internet and possibly by IoT. It is a new form of Call-for-Start-Ups, not based on the product but rather on the business model. The definition of the project should be completed by mid-2017, and the first funding opportunities could be available by the second half of 2017.

1.8 LUX-TIR OTT. The major winners in the business arena of the Information Society are the Over-The-Top (OTT) companies, such as Amazon, Facebook, Google, etc, who exploit the possibilities offered by the Internet without possessing any crucial part of the physical telecommunications infrastructure. At a moment when the discrepancy between offered traffic and average revenue per unit (ARPU) is growing dramatically, this translates into growing margins for OTTs and diminishing returns for telecom operators. Clearly, telecommunications companies in Luxembourg are already deciding their strategy in this crucial domain. The aim of the LUX-TIR OTT project is to give both incumbents and possible new start-ups a strong message in favor of the exploitation of the OTT business paradigm. Indeed, without this component, the Telecommunications infrastructure in Luxembourg will bring most of its benefits to companies based outside of the country.

[294] See: http://www.ilea.lu/html/automotive.html
[295] See: http://www.luxembourg.public.lu/en/actualites/2016/03/24-automotive-campus/index.html

2 Technical

2.1 LUX-TIR 5G. Regions around the world are investing in 5G, the new standard that will fundamentally transform the way society communicates by addressing three segments: ultra-broadband communications, the Internet of Things (IoT), and mission critical services. 5G systems and networks will constitute the essential and critical infrastructure of the economy of the future. Those countries that introduce 5G solutions first will enjoy an advantage in transitioning into the Third Industrial Revolution. Clearly, telecom industries in Luxembourg have their own strategy for 5G; yet, it is important to coordinate efforts in the country and in Europe since other regions around the world are quickly moving towards early experiments and deployments. The European Commission is therefore calling for an "Action Plan for 5G." The LUX-TIR 5G project aims at positioning Luxembourg as one of the first adopters in the 5G arena. Given that countries around the world are expected to develop 5G technology standards and regulations, Luxembourg should position itself strategically as a pilot region for demonstrating and testing 5G technologies and enter into a collaboration with Horizon 2020 5G-PPP to set up demonstration projects. This action is urgent, given that test demonstrations of 5G technologies will take place mainly in the 2017-2018 timeframe. Definition of the 5G plan and roll-out should be completely defined by the end of 2016.

2.2 LUX-TIR Satellite 5G. Luxembourg – thanks to the presence of SES – has a very strong position in satellite operations and, therefore, in the provision of broadcasting and broadband services. Until now, satellite technology has remained at the margin in the development of the 5G standard; this represents both a challenge and an opportunity. The goal of the LUX-TIR Satellite 5G project is to foster satellite technology and allow it to become an integral and integrated part of the network infrastructure of the future. The IoT can take advantage of the peculiarities of satellite communication. It is a fact that natural disasters stemming from climate change or human attacks, possibly of a terrorist nature, create the possibility to have disruptions of service in areas of variable size, from local to regional. These conditions must be prevented, detected, mitigated, and finally resolved as quickly as possible, in order to minimize their impact on society. In other words, Luxembourg will need to build a high degree of resilience into its communication network to address potentially catastrophic disruptions from climate change and cyberterrorism. It is therefore crucial for the telecommunications network to be both self-healing and redundant. 5G is designed to be a software-defined network, in which functions are virtualized over general purpose hardware. This is a key characteristic that allows the network to be reconfigured almost instantaneously, and services to be restored in minutes.

Therefore, the intrinsic resilience of 5G networks is much higher than that of previous technologies, both cellular and Wi-Fi. However, in the case of a major blackout, this degree of resilience may not be sufficient. In these conditions, it becomes necessary to have alternative means for communications which do not rely at all on ground infrastructure. Satellite communications, including the use of high-altitude platforms (e.g. stratospheric balloons), become the preferred back-up solution in extreme conditions. Clearly, this requires that satellite links and gateways be included and their characteristics duly considered in the design of the 5G network standard to assure a high level of resilience. Given these fundamental characteristics, a special R&D program on LUX-TIR satellite 5G technologies should be initiated as soon as possible.

2.3 LUX-TIR IoT Test-Bed. The TIR paradigm is based on the build out of IoT networks to interconnect people, cars, buildings, and cities with digital infrastructure to collect Big Data that can be processed to provide analytical information for strategic decision making. To date, IoT networks have been developed vertically with proprietary technologies. An institutional LUX-TIR IoT test-bed initiative would boost the development of open-source IoT technologies, positioning Luxembourg at the forefront of this crucial element of the smart-economy architecture. This should be done in conjunction with the seven lighthouse initiatives that have already been kickstarted in Luxembourg: High Power Computing (HPC); Big Data enabled applications; autonomous driving; smart city; smart space; smart energy; and FinTech. Some of these initiatives have been described in the Important Project of Common European Interest (IPCEI) document which establishes these projects as a top priority for the Luxembourg Government. The LUX-TIR IoT test-bed project aims at the development of a Luxembourg-wide wireless sensor network for IoT applications. Several applications can be addressed. For example, in the automotive sector, the IoT test-bed would aim at the collection of information from all cars transiting into the Luxembourg territory, to extract distributed information about traffic and pollution, and drive the decisions for corrective measures. Incentives should be given to those who participate in the LUX-TIR IoT test-bed initiatives, for example as discounts on tolls or insurance (which can be dynamically based on usage, routes, times schedule, and so on). It would be reasonable to define the scope of the LUX-TIR IoT test-bed project within the first quarter of 2017, for a start up in the second quarter of 2017.

2.4 LUX-TIR cross-institute initiative. Luxembourg has an impressive number of excellent initiatives and institutes in crucial sectors. For example: Luxembourg Centre for Systems Biomedicine (LCSB), Luxembourg Institute of Health (LIH), Luxembourg Institute of Socio-Economic Research (LISER), and Luxembourg Institute of Science and Technology (LIST). All of these sectors will be profoundly affected by the Third Industrial Revolution, and a complete understanding and mastery of the ensuing issues will entail an inter-disciplinary approach. In order to position Luxembourg in an anticipatory seat, it makes sense to design cross-institute initiatives with long-term ambitions and goals. The LUX-TIR cross-institute initiative aims at identifying research themes of common interest between LCSB, LIH, LISER, LIST, and the University of Luxembourg (and possibly other institutes) in the realm of the Third Industrial Revolution and its impact on the Smart Economy. Many of these themes can be funded for a short period of exploratory research, and the outcomes can be subject to independent review. Only a few selected themes should then be pursued for a longer term. Initial themes proposals: mid-2017. Exploratory phase: until end of 2017. Research on selected themes: 2018-2020.

2.5 Software Development. Software development skills are crucial in the IoT Economy. LUX could focus on developing and attracting talent in LUX-specific areas within this field. For example:

2.5.1 Migration of legacy application – as businesses and public organizations change the functioning of their ICT systems to adapt to new standards, migrating applications becomes a technology service and skill set.

2.5.2 Cloud architecture – many digital services are now consumed on virtual infrastructure found in numerous locations connected via the Internet (“the cloud”); applications are required to be optimized for this deployment and delivery model.

2.5.3 Mobile platforms – many applications now need to be optimized for tablets and smartphones. This impacts how mobile applications are managed and secured. Mobile platforms will increasingly run by secure containers (an authenticated encrypted area of a user's mobile device) which will enable the improved management of secure data on mobile devices that can be used to block sensitive corporate information from personal information.

2.5.4 Bespoke applications – while many applications are available off the shelf or as cloud-based services, the development of bespoke applications must be pursued to suit organizations’ specific infrastructure and needs.

2.5.5 User experience – the adoption of digital products and services is linked to the ease of use of the technology – both in the mass market and in specific areas such as health. The idea goes beyond design of the product and service and captures the complete set of interactions a user has with the provider.

3 Regulatory

3.1 E-Luxembourg: The Grand Duchy of Luxembourg will be the first country to offer comprehensive digital E-Registration to EU and non-EU individuals and companies.

3.1.1 E-Registration in Luxembourg will enable global E-Registrars to access a growing number of services and benefits at low cost and high speed through one unified, secure and easy online application portal, thus allowing them to access the entire EU market digitally through the trusted Luxembourg Digital Registration Gateway. This core strategy was inspired by E-Registration, E-Identity and E-Residency innovations and experiments in the State of Delaware (USA), Singapore, London and Estonia and further develops these early stage conceptual frameworks to fit the specific Luxembourg ecosystem and its unique role as the EU's first nation state and test lab for EU-wide regulation. The goal is to establish Luxembourg as the first country to successfully implement trust- and technology-driven E-Registration on a large and lucrative scale.

3.1.2 One of these initial services will be centered on company creation: Luxembourg will be the first country in Europe that allows the establishment of a fully-fledged European company with headquarters in Luxembourg with a few clicks online.

3.1.3 Register a new company over the internet; Change data in the business register; File annual reports; Detailed inquiries about other companies; Digitally sign documents and contracts; Encrypt and transmit documents securely; Administer the company from anywhere in the world; Conduct e-banking and remote money transfers; Access online payment providers; Declare taxes online; Inclusion in EU legal framework.

3.2 Make Luxembourg a Pioneer in realization of General Data Protection Regulation for the Financial Industry. The achieved legal security will result in a competitive advantage for the Financial Sector. According to the European Parliament, the new rules of the General Data Protection Regulation include provisions on:

3.2.1 Right to be forgotten; "Clear and affirmative consent" to the processing of private data by the person concerned; Right to transfer data to another service provider; The right to know when your data has been hacked; Ensuring that privacy policies are explained in clear and understandable language; and stronger enforcement and fines up to 4% of firms' total worldwide annual turnover as a deterrent.

3.3 LUX-TIR Net Neutrality. Openness and Internet transparency are clearly desirable in order to create the best possible conditions for TIR businesses. However, mission critical services, as well as business models based on the freemium paradigm, require the possibility to modulate the Quality of Experience (QoE) provided to the final users of the infrastructure.

Finding the best possible compromise between these two conflicting elements is a very important issue that should be tackled at the European level: the LUX-TIR Net Neutrality initiative aims at contributing to this effort with a study on defining a regulatory framework that will allow both content agnostic-network operation and smart QoE provisions. These apparently conflicting goals should be addressed with an end-to-end approach in mind, very similar to the concept that brought to life the Internet itself. The regulatory framework should be layered, with neutrality increasing towards the lower layers of the regulatory stack. The Net Neutrality initiative could be defined in the first half of 2017 and run for one year, until mid-2018.

3.4 **Develop a LUX-TIR Digital Rights Declaration and Accompanying Regulations.** The Third Industrial Revolution will bring to life new forms of society, with the coexistence of human beings and advanced forms of artificial intelligence, anthropomorphic and non-anthropomorphic. Interconnections between humans and things will constitute the fabric of interaction, information exchange, transactions, and decision making. Exclusion from this network of interconnections will be a new kind of impoverishment and injustice. A definition of the concept of digital rights, which is a subject of active debate today, will be necessary as well as the definition of a regulatory framework to ensure that these digital rights are guaranteed to all. As for the previous point, this is an issue that must be tackled at the European level. The LUX-TIR Digital Rights project aims at exploring what contribution Luxembourg can make to this fundamental issue, taking advantage of its small size and sovereignty. The overall objective could be to make Luxembourg a flagship in the domain of Digital Rights provision. The widespread ICT infrastructure which is available today is an excellent starting point to eliminate any forms of digital divide. Definition of the Digital Rights strategy for Luxembourg could be completed by the first quarter of 2017. Ensuing actions could follow in the next three years.

3.5 **LUX-TIR Future Spectrum**. One of the critical elements of the 5G network will be the exploitation of the millimeter-wave spectrum for ultra-broadband interconnections with peak data rates up to 10 Gbit/s. Several frequency bands in the range from 27 to 86 GHz have been designated during the World-Radio Conference 2015 (WRC-15) to study their possible application to future 5G networks. Final decisions will be made at the next World-Radio Conference in 2019, WRC-19. In view of the LUX-TIR 5G project described above, Luxembourg can take a proactive regulatory approach to the spectrum. The LUX-TIR future spectrum project aims at the identification of specific portions of the millimeter-wave spectrum to be used for experimentation over the Luxembourg territory. This project only makes sense in conjunction with the LUX-TIR 5G and LUX-TIR satellite 5G initiatives. In identifying these bands, great care must be taken to the allocations for terrestrial and satellite segments, ensuring both a path to the digital future and a guarantee for present investments. Decisions on spectrum must be made within the first half of 2017.

3.6 LUX-TIR Private Transparency. The title of this project clearly contains an oxymoron, which reflects the contrasting needs of providing privacy, trust, and security on one side, and availability of data for analytics on the other side. Striking the best balance between these needs is clearly a crucial issue. The LUX-TIR Private Transparency project aims at launching a regulatory study for the identification of measures that can provide the necessary interface between individuals who should be protected and big data applications, which should be enabled. Alternative anonymization procedures should be considered, benchmarked and tested. This project could benefit from the collaboration of several institutes, such as LIST, LISER, the University of Luxembourg, as well as the Government. It is a medium term project with a life span of around three years.

4 Public Policy

4.1 Institutionalize the implementation of a national steering committee tailored after the Singapore 2025 model, composed of a mix of inside and outside experts, elected officials, business leaders, academics, and civil society organizations, with an independent budget and direct access to political decision makers, that can work with neighborhoods, the school system, and local businesses, with the mission of providing an ongoing public forum that can engage the entire country in the transition to a smart Digital Luxembourg.

4.2 Early adoption through strategic and expert customers: The Luxembourg Government and leading Luxembourg corporations should position themselves as strategic customers and test vehicles (compare the high-tech digital strategy of German Post and German SINTEG in energy).

4.2.1 Create an agile delivery process that responds to the changing requirements of purchasing of ICT products and services to ensure solutions meet requirements.

4.2.2 Ensure that Luxembourg has an exemplar digital infrastructure in and around urban areas and administrative units.

4.2.3 Provide an integrated, agile platform, based on open standards which expose appropriate data and service APIs to nurture the development of an innovative ecosystem.

4.2.4 E-Procurement: Make it easier for local businesses, particularly SMEs, to do business with the Luxembourg Government.

4.3 Digital Inclusion. Digital inclusion in Luxembourg should consider not only future generations but also the current generation. The global population is ageing rapidly. Between 2000 and 2050, the proportion of the world's population over 60 years will double from about 11% to 22%. The absolute number of people aged 60 years and over is expected to increase from 605 million to 2 billion over the same period. Luxembourg should examine methods and programs to deepen the understanding of disruptive technologies as well as their utility and the opportunities they bring to all age cohorts across Luxembourg's society.

4.4 Luxembourg should examine the formulation of public policymakers' tools to foster a local Venture Ecosystem comparable to what the Coller Institute developed for the VC ecosystem in Israel. These tools should focus on three areas: 1. funding, 2. taxation, 3. stock market access.

4.5 E-Luxembourg as Core Strategic Vision. Setting up more open approaches to policymaking and public service delivery requires governments to re-organize themselves around user expectations, needs and associated requirements, rather than their own internal logic and needs. The "Recommendation of the Council on Digital Government Strategies" of the OECD states:[296] "The challenge is not to introduce digital technologies into public administrations; it is to integrate their use into public sector modernization efforts. Public sector capacities, workflows, business processes, operations, methodologies and frameworks need to be adapted to the rapidly evolving dynamics and relations between the stakeholders that are already enabled – and in many instances empowered – by the digital environment. To this end, digital government strategies need to become firmly embedded in mainstream modernization policies and service design so that the relevant stakeholders outside of government are included and feel ownership for the final outcomes of major policy reforms."

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[296] See: http://www.oecd.org/gov/digital-government/Recommendation-digital-government-strategies.pdf

5 Financial

5.1 LUX-TIR FINTECH. Next generation Fintech brings together the world of finance with the new opportunities brought forth by the build out and scale up of a Third Industrial Revolution infrastructure and the new business models and practices that accompany it. Given the key relevance of the financial sector in Luxembourg, Fintech for SMEs is a formidable opportunity. SMEs often suffer from inadequate funding because the finances of SMEs are characterized by high risk and low scale. Because FinTech solutions are efficient and effective at lower scale, small businesses will be one of the main beneficiaries of FinTech's disruptive power. The LUX-TIR FinTech project aims at developing a new set of products tailored to the needs of small businesses. Funding initiatives can include: "peer-to-peer" lending, merchant and e-commerce finance, invoice finance, online supply chain finance, online trade finance, etc. The LUX-TIR FinTech project should consider both the enabling factors that are critical to ensure rapid growth (availability of data, a supportive regulatory environment, the provision of sufficient investor capital, financial education) and the relevant risk factors (limited protection of retail investors, potential extension of funding to unworthy borrowers, systemic risk due to a partly unregulated sector).

6 Educational

6.1 The LUX-TIR Education for Creativity project aims at bringing Luxembourg to the forefront in the design of new educational curricula for the citizens of the future post-TIR society. Start-up ecosystems thrive in multidisciplinary settings. Luxembourg could develop (in collaboration with public and private organizations) specific TIR-related interdisciplinary curricula, projects and programs at universities, incubators, start-up competitions and international entrepreneur exchange programs to foster entrepreneurship and commercialization. Compare the GSVA (German Silicon Valley Accelerator) and German EXIST Program. Both domain-general and domain-specific approaches to creative thinking should be contemplated. Neuroscientific, cognitive, social, and cultural perspectives must be considered. Theoretical and practical approaches to idea generation must be developed and transformed into subjects for schools, universities, as well as life-long training programs.

6.2 Introduce Scratch to Luxembourg schools. Mitch Resnick at the MIT Media Lab helped create Scratch and ScratchJr., computer languages designed expressly to introduce children to programming: "Coding is not just a set of technical skills. It's a new way of expressing yourself. It's similar to learning to write — a way for kids to organize, express and share ideas. But instead of putting words into sentences, now they can create animated stories."

6.3 Educate the educators. The teacher pipeline is one of the biggest issues in teaching computer science. Currently in Luxembourg, there is no certification for teaching computer science. We're merely taking people who trained to be teachers and giving them some CS knowledge so they can step into a classroom and help kids. Luxembourg needs to ratchet up the qualifications of teachers overseeing computer science instruction.

6.4 Involve the local tech industry. Luxembourg should better mobilize companies and research institutions to engage their engineers and scientists to volunteer in schools, to talk in the classroom, or run a whole-day hackathon – like Google did last year at the Academy for Software Engineering – or job shadowing, or taking students on as mentees.

7 Research, Development and Innovation

7.1 Strengthen partnerships with applied science organizations such as Fraunhofer Society to foster the transfer of E-Luxembourg academic know-how into the economy and society. LIST is on a good path but not yet sufficiently focused, staffed, funded and embedded in international applied science structures to fulfill its role as intermediary between academic R&D and concrete E-Luxembourg business, society and government applications. Therefore, partnerships with larger and international applied science networks will be necessary.

7.2 LUX-TIR Decentralized Exploration. Luxembourg's approach to providing financial support to R&D and new entrepreneurship has been characterized so far by a high degree of centralization. The main emphasis has been placed on firms that drive economic growth and job creation, with a strong pre-screening role enforced by LuxInnovation, tasked with the objective of eliminating immature project ideas even before requests for funding. This approach is both sensible and rational; the only problem is that it very rarely leads to disruptive innovation, as one would expect to come out of the United States, where "failure" is very much tolerated in favor of taking very significant risks towards disruptive objectives (Silicon Valley being the first example). The aim of the LUX-TIR Decentralized Exploration project is to introduce a new balance in the financial support of RDI to encourage the funding of more unfiltered risk-taking and potentially disruptive innovation actions. An 80/20 split (or even 90/10) might be appropriate: 80% of the resources could remain in line with current risk standards, while 20% of the resources could be dedicated to supporting (with a relatively moderate funding grant per item) more exploratory projects that have relatively small probability of success, but with significant potential for disruption if their goals are achieved.

7.3 LUX-TIR One-for-One PPP. A clear trend in providing financial support to RDI for industry is to form public-private partnerships (PPPs) that have the main purpose of using public funding to leverage an equal (or higher) investment by the private side. For clear reasons of strategic business protection, it is usually very hard to actually quantify the investment from the private side, which may somewhat limit the effectiveness of the PPP. The aim of the LUX-TIR One-for-One PPP project is to formulate an alternative form of PPP in view of the distributed collaboration schemes that will characterize the post-Third Industrial Revolution society. The idea is that for each unit of public funding that a company receives for the support of strategic RDI, the company must invest an equal amount for outsourced research, commissioned to either the University of Luxembourg, or to research institutes in Luxembourg, or even strategic (but public) research partners from Europe and around the world. This mechanism holds the potential of boosting the open innovation paradigm.

CIRCULAR ECONOMY

OVERVIEW

Co-Chairs Jeannot Schroeder and Carole Wammer, and the Luxembourg Circular Economy Working Group;

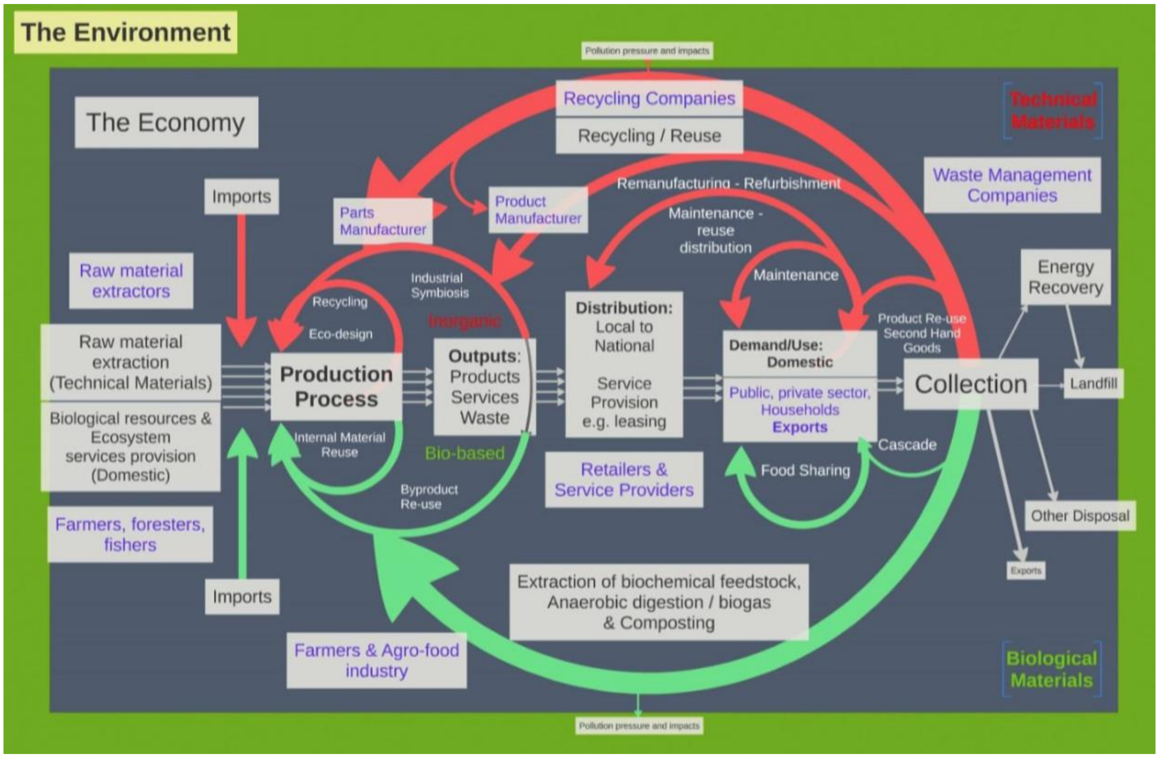
Michael Totten (Assetsforlife.net) and Jeremy Rifkin, TIR Consulting Group LLC

An initial analysis by the TIR consulting team suggests that for every euro of economic activity, the Luxembourg economy generates about 2.5 kilograms of waste. Yet, there are promising developments in the steel and chemical industries, the food and agricultural sector, as well as in financial services and the development of information technologies (among others) to suggest that such wastes can be profitably reduced over time and that investments can be planned and implemented to increase overall economic productivity.

The Circular Economy (also called circularity) is both indispensable to the goal of increasing aggregate efficiencies and reducing ecological footprint, as well as a source of new innovations with multiple ancillary benefits. The circular economy is designed to mimic the material and energy flows in mature ecosystems where resources are continuously appropriated, used, redistributed, and recycled for future use. Circularity spans three areas: the production of goods and services, consumption and behavior, and waste valorisation.

These fields are expressed in seven pillars: sustainable supply, eco-design, industrial ecology, functional economy (or functionality), responsible consumption, increase of the life duration, and recycling. Sustainable supply concerns the way resources are extracted with the goal of minimizing the environmental impact and optimizing the extraction process. It is valid for energy and minerals, but also for agriculture and forestry. Eco-design addresses all the ways to improve the environmental impacts of goods, optimizing the aggregate efficiency of matter used, including life-cycle analyses. Industrial and territorial ecology mediates the relationship between the biosphere and human societies through the knowledge of material and energy flows across economies. The functional economy emphasizes the use of a product rather than its ownership. Responsible consumption focuses on making economic choices based on evaluating the sustainable life cycle of a product or service. Recycling is a well-known process by which used products are re-introduced into the industrial chain of production. For example, currently, small companies are manufacturing 3D printed products from recycled plastic, paper, and metal objects.

Simplified illustration of a circular economy



Source: EU (2014) Scoping study to identify potential circular economy actions, priority sectors, material flows & value chains, prepared by PSI/IEEP/Bio/Ecologic, representation by, Patrick ten Brink, P Razzini, S. Withana and E. van Dijl (IEEP), 2014, report funded by Environment's Framework contract for economic analysis ENV.F.1/FRA/2010/0044.

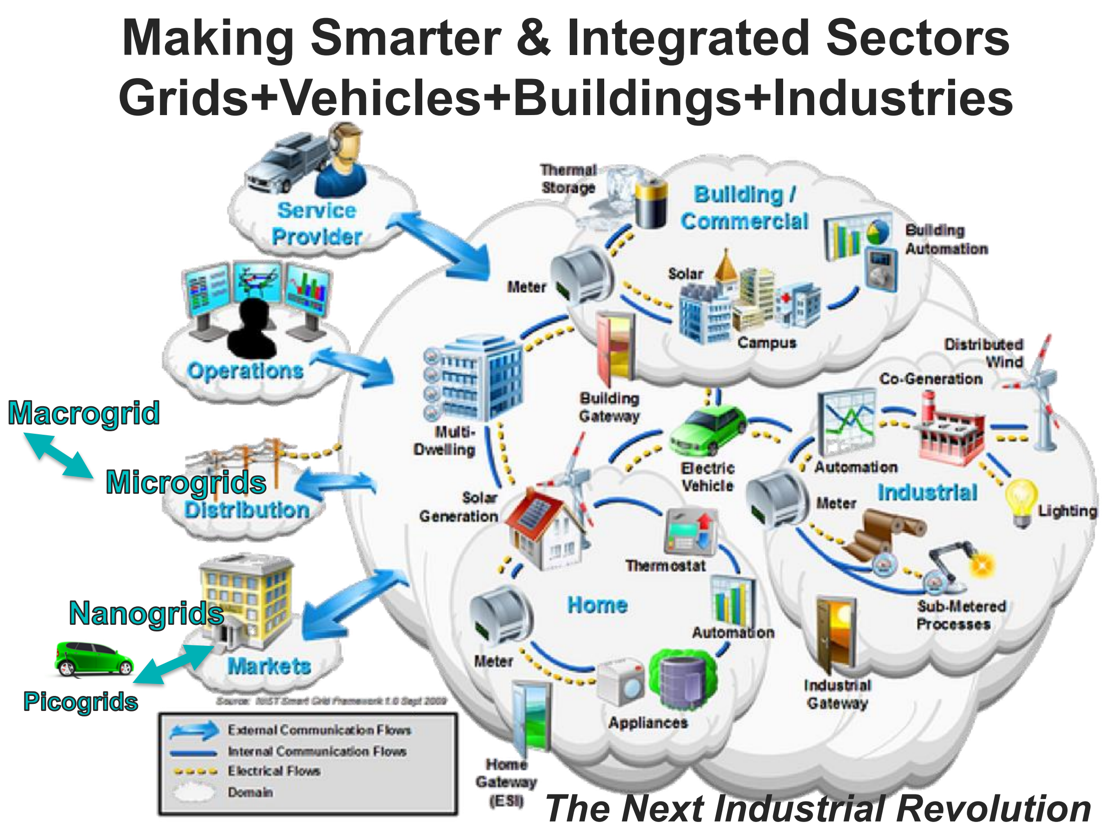
The Renault plant in Choisy-le-Roi outside Paris is a good example of circularity across a company's value chain. The Renault plant "remanufactures" automotive engines, transmissions, injection pumps, and other parts for retail. The plant facilities use 80% less energy, 90% less water, and generate 70% less oil and detergent waste in its operations than its competitors, giving it higher operating margins.

Renault designs its parts to make them easier to disassemble and reuse. Renault also collaborates in joint ventures with a steel recycler and waste management company to secure the necessary expertise to optimize the lifecycle of their parts. Finally, Renault motivates its suppliers to increase aggregate efficiencies and reduce waste in the supply chain by rewarding them based on performance contracts – paying them for the efficiency gains – rather than simply paying for the purchase of the goods.

It should be emphasized that the circular economy is much more than recycling and restoration of materials used. Keeping resources in circulation for as long as possible is also a critical aspect of the circular economy. In the Sharing Economy, the increase in product usage means extracting higher value from the resources. This leads to an increase in aggregate efficiency and productivity. An Accenture assessment projects that savings in materials, recycling, and restoration, will likely exceed $4.5 trillion by 2030 in the global economy while increasing productivity, reducing fixed and marginal costs, creating net new jobs, and lowering ecological footprint.[297]

The maturing of an interconnected digital network composed of the Communication Internet, Energy Internet, and Mobility Internet enables individuals, small and large businesses, non-profits, and other institutions to use High Performance Computing (HPC) and Big Data Analytics (BDA), along with machine intelligent (cognitive computing) algorithms to continuously increase these interconnected Internet networks' aggregate efficiencies and reduce their ecological footprint *in managing, powering, and moving* economic activity in a virtuous circular economy.

[297] See: https://newsroom.accenture.com/news/the-circular-economy-could-unlock-4-5-trillion-of-economic-growth-finds-new-book-by-accenture.htm



Recall, aggregate efficiency measures the ratio of potential to useful work in every economic conversion. The higher the aggregate efficiency, the less material and energy are wasted in the conversion process. The build-out of an IoT infrastructure across Luxembourg provides a technological platform for tightening circularity across every conversion on every value chain. The IoT platform also assists circularity in another way. By reducing the marginal cost of producing and distributing virtual and physical goods to near zero, the IoT fosters the growth of the Sharing Economy. The Sharing Economy is by its very nature a circular economy. Goods and services are redistributed over and over, enabling a much higher efficiency per used resource.

The Luxembourg EcoInnovation Cluster of the Ministry of the Economy and the Ministry of Sustainable Development and Infrastructure is charged with the responsibility of advancing the circular economy, green mobility, and sustainable cities and smart technologies. The mission of the Luxembourg EcoInnovation Cluster is to assist companies in the promotion of eco-technologies, the development of new environmental solutions, particularly in sustainable construction, building public awareness around green technologies, and promoting public-private partnerships to advance a smart sustainable Luxembourg. The Luxembourg

EcoInnovation Cluster will play a key role in advancing a circular economy across all of Luxembourg's industrial sectors as the country transitions into a low-carbon sustainable economy.

LUXEMBOURG STATE OF PLAY AND VISION

Our thinking is largely dominated by linear mindsets where the increase in consumption is at the center of economic growth. Most of the companies operate their businesses based on traditional economic concepts, and existing infrastructure is designed around this linear model. Continuing to design, construct and operate the economic infrastructure and built environment in a linear fashion incurs greater risks and expenditures, increasing opportunity losses and costs, including failures to future proof against system shocks, uncertainties and surprises. In sharp contrast, shifting to a circular model in designing, constructing and operating infrastructure and the built environment goes beyond restorative features and enhances the qualities of resilience, robustness, flexibility, and anti-fragility, that are best positioned to respond to future uncertainties and surprises. Neglecting or delaying the shift results in more expensive retrofits in the future or passing on opportunities to retrofit because of excessive costs. A crucial aspect of circularity is to perform penetrating assessments of why and what infrastructure is needed – the (multi-)functional benefits to be gained – and then apply deep design practices integral to achieving circular economy outcomes. The objective is to establish design principles that lead to "feeding products, components, and materials back into the appropriate value chains," resulting in "a healthy economy that is inspired by and in balance with nature."[298]

The positive attributes resulting from shifting to a circular economy are applicable to the entire throughput stream of economic activities, processes, and supply networks. Existing supply chains are very often highly complex and long and make it almost impossible for the final producers to identify all the materials, components and ingredients, which have been used in the goods they sell. Most companies have suppliers from outside Luxembourg, and even from outside Europe.

The awareness of these issues is increasing and there are several promising initiatives currently underway to incentivize a circular economy in Luxembourg. Actors from government and private research institutes have been pooling their skills through a technology platform established within the "Luxembourg Institute for Science and Technology" (LIST) to boost the

[298] Circle-Economy (2014) Designing for a circular world: circular design principles, October 06, 2014, www.circle-economy.com/designing-circular-world-circular-design-principles/.

development and processing of innovative materials in fields like the automotive industry and aeronautics. It is estimated that the composite materials sector in Luxembourg is already generating a turnover of almost € 400 million per year and employs 1,600 people. Launched in 2016, the future National Competence Center will employ 60 people when fully operational.

Today, it is nearly impossible to know the exact composition of end user consumer products (down to parts per million [ppm] levels). If the goal is to maintain a high quality throughout the use and re-use (up-cycling) phase, it is essential to know the exact composition of the material. This issue is further complicated by the protection of intellectual property.

Moreover, implementing circularity across the value chains in Luxembourg is complicated by the issue of storage and security of data. Widespread protection of product recipes by the companies prevents a transparent exchange of information. As a result, many of the components that make up the supply chain remain unknown even to the final manufacturer of a finished consumer good. Blockchain could be a solution. A decentralized collection of data allows every enterprise across a specific supply chain to track information on materials and to store it in a secure way. Due to Luxembourg's strong ICT commitment, the country boasts several young ICT companies actively engaged in research on blockchain processes. At this stage the development is highly Fintech oriented but could easily be adaptable to general data storage and material information tracking.

Luxembourg's IT infrastructure is among the best and most secure in Europe and the world and is complimented by excellent network coverage. The investments in the digital infrastructure over the last decade should be fully exploited to generate economic activity on a cross sectorial basis. The recently announced "Important project of common European interest on high performance computing and big data enabled applications (IPCEI-HPC-BDA)," in which Luxembourg will play a key role, will further strengthen the ICT ecosystem of the Grand Duchy by adding a strong HPC (High Performance Computing) competence and granting access to exceptional computation power for simulation and data processing purposes.

While the current thinking in Luxembourg is technology-driven, there is not enough focus given to biological resources; i.e. how biological materials flow back and forth through the technical supply chain cycle and the subsequent impacts on biological resources that result from overreliance on a linear consumption model. Environmental and social burdens and costs are rarely internalized in the process/product but, rather, transferred to the public sector or society at large. The post-consumer material cycle illustrates that there is, as yet, a lack of a common view on what is 'waste' and how it should be treated. Moreover, current regulations and the large number of actors in the decision making process may significantly delay the implementation of new ideas. Indeed, current national and international regulations often prevent a circular approach.

Furthermore, the existing infrastructure is poorly designed for reverse logistics, and large scale recycling units are blending many different products within only one material category. In this way, all the different material compositions get lost and the quality and economic value of the resulting blend tends to be poor. Global supply chains make it difficult to precisely define material flows and close loops at the local or regional level. Big players like the telecommunication company POST have meanwhile recognized the issue and developed a business case around reverse logistics. There is now, more than ever, an opportunity to invest in reverse logistics and to combine it with either technical skills (repair service) or lower skilled jobs around the dismantling and recovery of resources.

It will be very difficult to overcome a cultural reluctance to fully understand the concept of what a circular economy really means. Conventional cultural values present a set of challenges, linked to a conservative Luxemburgish approach that is based on possession of goods.

The general awareness about the circular economy in Luxembourg is still in the starting blocks. Luxembourg’s business community is increasingly interested in the circular economy as it understands not only the sustainability aspects, but also the economic advantage of implementing circularity across the value chains. Many initiatives have been taken by the Government (the ministry of economy and the ministry of sustainable development and infrastructure), the chambers of commerce and craft trades, as well as the EcoInnovation Cluster. The recent participation of Luxembourg in the “Incoming Trade Mission” organized by the Netherlands CE Hotspot has lead to a new CE Hotspot summit that will be organized by Luxembourg in 2017.

Education and communication will be critical to the success of a circular economy in Luxembourg. To date, there are only a few possibilities to undergo CE training. Unfortunately, Luxembourg’s labor force does not yet have the right work skills to make use of the existing technology. Efforts should be undertaken both on a primary and secondary school level, during apprenticeships and university studies, as well as life-long learning initiatives to prepare the Luxembourger workforce with circularity principles and practices. Teachers have to be retrained as well.

Luxembourg has several organizations (like “SuperDreckskëscht”) that currently reach out to a high number of companies and citizens, and which could be key actors in fostering a growing awareness of the vast merits in introducing circularity across every aspect of Luxembourg’s society.

Luxembourg’s financial sector has a key role to play in the transition to a circular economy.

Initial investments may be higher than those for the linear model and full benefits can only be realized once all the elements are in place. Currently, the linear model is encouraging the use of cheap raw materials to advance short-term financial gains. Therefore, it is difficult to anticipate a business change, which competes with the linear thinking. The public sector could easily play a key role in encouraging the "pay for performance" concept in which return on investments are secured by the increase in aggregate efficiencies and productivity and reduction in marginal cost and ecological footprint.

Luxembourg is also developing the logistics infrastructure. Luxembourg's mobility landscape is changing rapidly. The national telematics project, the new tramway and a new railway station granting direct access to the business center of Kirchberg are three visible examples of this evolution. At the same time, mobility is changing globally. Car and bike sharing initiatives are emerging in ever more cities, hybrid and electric buses and cars are appearing on our roads while owning a car is becoming less and less attractive. Access to mobility starts to replace ownership.

Luxembourg's Circularity Vision

Luxembourg will be the first circular nation, where new business models based on the product-as-a-service principle become standard. All public procurement will be aligned around the circular economy. Contracts will be performance-based. Luxembourg will have developed know-how around eco-design and product life assessment. Luxembourg will have an adapted resilient infrastructure that promotes local renewable energy production, storage and sharing, short and local resource loops, a continuous water loop and reverse logistics. In addition, the new infrastructure, designed to fully integrate CE principles, will be able to manage (in terms of storage and calculation) a large set of data, linked to each product. Luxembourg will have created a legal framework that allows the exchange of product related information between suppliers, by guaranteeing a level of confidentiality. The national tax system will support companies implementing a circular approach. Luxembourg will have gained the technical experience to make life cycle assessments and to evaluate how circular a business is.

Moreover, Luxembourg will have a detailed national measurement system in order to determine both quantity and quality of the different material flows. Luxembourg needs to become a key actor in the greater region in order to establish regional and/or local supplier communities and will contribute significantly to close these loops. In addition, Luxembourg will implement a series of seamless biological loops.

The above-stated goals will be achievable if we make eco-design and the basic principles of the circular economy part of our education and life-long training system. With the circular vision, the word 'waste' no longer exists. Circular education will teach the students the necessary skills needed to innovate and move towards a circular economy. Future generations will be able to adapt and cope with constant change, and will have a deeper systemic understanding of the biological cycle and be capable of using the latest technologies to create a virtuous circular society.

A clear opportunity for Luxembourg is the commitment from the current government to implement a circular economy strategy. An effective local network will need to be backed by a strong financial sector.

With the government's full support and the right legal framework, Luxembourg could become the global center for a "safe but transparent" approach to products as services. Such a transparent approach empowers prosumers and companies by providing the tools for a distributed and decentralized approach to marshalling local materials and creating seamless product loops in line with the TIR philosophy of establishing a distributed, transparent, and democratic approach to renewable energy production.

Interconnecting the Circular Economy

Just as circularity is indispensable to the goal of increasing aggregate efficiencies and reducing ecological footprints, it is, in turn, contingent upon an interconnected digital network composed of the Communication Internet, Energy Internet, and Mobility Internet *in managing, powering, and moving* economic activity in a virtuous circular economy (CE).

The scale and complexity of the European Union's €14.3 trillion economy, let alone the €70 trillion global economy, is so vast and data-massive that to perform the granular-scale tracking of energy, materials, chemicals, water, and related levels of emissions, air and water pollutants, hazardous wastes, soil contaminants, sewage and toxic effluents requires advanced computing technologies integrated with the Internet of Things, Services and Networks (IoT, IoS, IoN).

The world produces a prodigious quantity of data, information and knowledge – as much in 24 months than in recorded history, according to Google Chairman Eric Schmidt. Data usage over the Internet in 2016 is projected to exceed a trillion gigabytes, or one zettabyte, and this amount is predicted to double over the next 36 months. More than 10 billion devices are connected to the Internet and that number may explode 10,000-fold to 100 trillion Internet connected wireless smart sensor network devices within the next 15 years (see visual below). Such exponential growth rates have been most recently witnessed with mobile phones. Mobile data traffic has grown nearly 400-million-fold over the past 15 years, according to Cisco's 2016 Visual Networking Index report.

Luxembourg is poised to take advantage of this extraordinary techno-takeoff. Over the past 15 years the nation has quintupled its public R&D support, with a strong focus on advanced ICT

(HPC and BDA) to help power the engine of a knowledge-based economy. This public commitment has attracted top-flight researchers. A February 2016 review by the European Commission highlighted the fact that Luxembourg's "scientific performance of the public research system has progressed very rapidly and is now above the EU average."[299]

RDI and the Greater Region

Luxembourg is strategically located to foster circular economy innovation in material and resource advances. Over half of the nation's public R&D funding supports companies in applied research on materials, and there is solid co-operation on materials with the Greater Region. The Greater Region can be leveraged as a Circular R&D Community for Materials development. The IntermatGR university consortium engaged in research on materials is a case in point. Research areas include biobased additives and composites designed for circular cycles; Designs for disassembly, as well as robotic-assisted disassembly; 3D additive manufacturing and de-manufacturing; Adapting Life Cycle Assessment to measure positive impacts; and joint progress in revalorization processing (e.g. concrete recycling). Luxembourg also consistently ranks among the top EU Innovators, as indicated in the annual Innovation Union Scorecard.[300]

The circular economy is already "a competitive imperative for Luxembourg," according to the conclusion of the 508-page commissioned study entitled *Luxembourg as a Knowledge Capital and Testing Ground for the Circular Economy, National Roadmap for Positive Impacts*.[301] Luxembourg's industry sector is singled out as demonstrating leadership on circularity. Companies, including ArcelorMittal (steel), Eurofoil and Norsk (aluminum), Guardian Industries (glass), Tarkett (flooring), and Tontarelli (plastics) are among the industrial leaders in implementing circularity across their value chains.

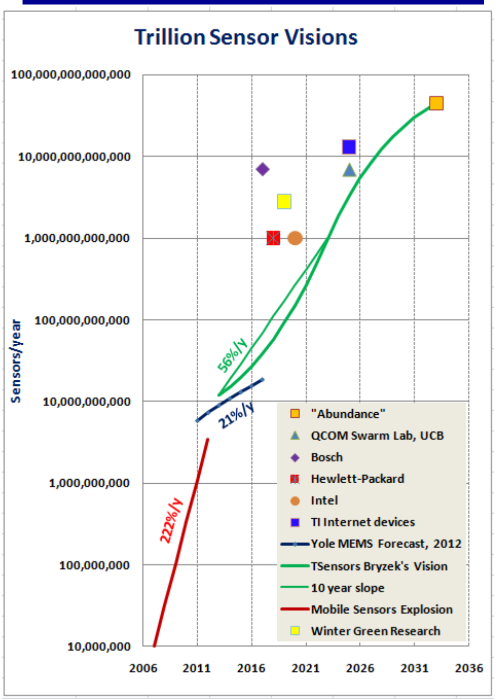
[299] EC (2016) *Commission Staff Working Document, Country Report Luxembourg*, European Commission, Brussels, February 26, 2016, SWD (2016) 84, http://ec.europa.eu/europe2020/making-it-happen/country-specific recommendations/index_en.htm

[300] EC (2015) *Innovation Union Scoreboard 2015*, by Hugo Hollanders, Nordine Es-Sadki and Minna Kanerva fromMaastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT) as part of the European Innovation Scoreboards project for the European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs.

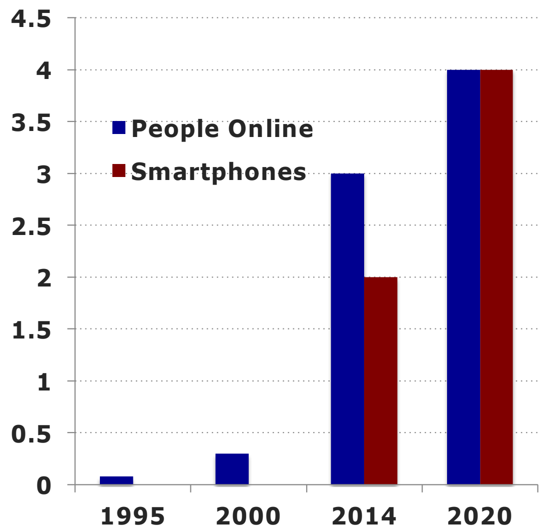
[301] Katja Hansen, Douglas Mulhall and Markus Zils (2014) *Luxembourg as a Knowledge Capital and Testing Ground for the Circular Economy, National Roadmap for Positive Impacts. Tradition, Transition, Transformation*, prepared for Ministry of the Economy Grand Duchy of Luxembourg, byEPEA Internationale Umweltforschung GmbH in association with Returnity Partners, December 18, 2014.

Two *Explosive* Exponential Trends driving IP addressable Internet of Everything (IoE)

Machine-to-Machine (M2M)



People Online (billions)



Source: Benedict Evans, Industrial Internet,11-2014, Partner, Andreesen-Horowitz; and, B. Evans, Mobile Is Eating the World, May 2013

(Left) Road Map for the Trillion Sensor Universe, 11/2013, Janusz Bryzek,VP, MEMS and Sensing Solutions, Fairchild Semiconductor

Luxembourg is also advancing circularity in the Sharing Economy with automotive leasing and car sharing, as well as leasing and sharing of building equipment by companies like Floow2 (B2B Internet marketplace) and Loxam, a pioneer in construction and industry equipment rentals.

An estimated €1 billion of circular economy activities currently occur in Luxembourg, employing upwards of 15,000 citizens, mainly in industry, as well as in buildings and construction, and retailing. Retailers like Oikopolis (organic produce) and Cactus (supermarkets) have cultivated supplier networks for local products. Traditional resource management firms like SDK (waste recycling), Valorlux (management of household packaging waste flows), and Ecotrel (WEEE compliance collection and recycling) are promoting innovative approaches to educate the public on circularity through mobile apps.

The near-term potential value in advancing Luxembourg's circularity practices is estimated to approach €1 billion annual net-material cost savings, including generating several thousand jobs within 36 months. This would require scaling circular activities throughout the automotive, construction, financial, logistics, manufacturing, and RDI sectors. Several dozen actions are underway in Luxembourg to expedite circular economy benefits.

Regional and Global Export Growth Opportunities

Circularity is viewed as a local opportunity as well as an export opportunity, given the massive global economic potential. The report, *Luxembourg as a Knowledge Capital and Testing Ground for the Circular Economy,* highlights the €7 trillion in renewable energy economic growth worldwide, and how Luxembourg's key industries could prosper by providing the important material components, including manufactured steel, glass and carbon composites. Luxembourg's financial sector, with some €3 trillion of investment funds, could also play a critical role in financing circularity across the 28 Member States. That estimate may seem high, but it turns out to be very modest.

Consider the following renewable power examples for wind and solar, which are discussed in greater detail in the TIR Strategy Study chapter on Industry. Luxembourg's ArcelorMittal is a major player in the wind power industry, most recently involved in providing the steel for constructing the 30 MW wind platforms off the cost of Scotland. Each MW required roughly 116 tons of ArcelorMittal's (recycled) steel.

How many megawatts of wind power could be installed at competitive prices over the next three decades? The most recent nation-by-nation world renewable energy assessment provides illustrative calculations.[302] One-third of total global energy needs can be satisfied with 1.96 million turbines of 5 MW each (1.2 million offshore and 0.76 million onshore). The calculated world market opportunity amounts to more than €19 trillion (2016€) between now and 2050. And how much steel would it demand? Assuming 500 tonnes of steel per 5 MW turbine, the total global amount would be more than one billion tonnes, or roughly 12 times the amount of steel ArcelorMittal shipped in 2014.

[302] Jacobson, Mark and Mark Delucchi *et al*. (2015) 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All- Sector Energy Roadmaps for 139 Countries of the World, December 2015, https://web.stanford.edu/group/efmh/jacobson/Articles/I/susenergy2030.html.

Product-as-a-Service

Wind power has multiple aspects contributing to a circular economy. The reuse and remanufacture attributes of wind towers, turbine blades, and platforms nicely comport with the wind industry evolving towards the products-as-services business model. Some 80% of the materials required to build and install a wind turbine are steel. Steel is the most reused and recycled material on earth. Over 90% of steel produced is both reusable and recyclable over and over again. At the end of a wind turbine's useful life, the tower can be recycled, remanufactured and reused, further extending its useful life, and eventually 90 to 100 percent of the steel is recaptured and recycled *ad infinitum*.[303]

The benefits of recycled steel are clear when compared to producing steel from virgin ores. Producing 1 tonne of steel from iron ore in the blast furnace (*BF*) to basic oxygen furnace requires 1.4 t of iron ore, 0.8 t of coal, 0.3 t of limestone, and roughly 1/8th of a tonne of recycled steel. Producing the same tonne in an electric arc furnace (EAF) begins with 0.88 tonnes of recycled steel, and requires 50 times less coal (16 kg) and nearly five times less limestone (64 kg). In addition, recycling steel requires significantly fewer inputs: 90% less virgin materials 75% less energy, and 40% less water; and, significantly lower outputs: 97% less mining waste, 86% less air pollutants, and 76% less water pollutants.[304]

Incenting Better Circularity Practices

Luxembourg has embraced the principle of polluter pays and user pays, yet there are many resources consumed annually in the economy that end up as discharged waste, emissions, pollutants, and contaminants.

In the case of the circular economy, diminishing these externalities is advanced by creative ingenuity, invention and innovation in designing, producing, delivering and consuming these goods and services, and ultimately and ideally, in a cradle-to-cradle, waste-as-nutrients circular process.

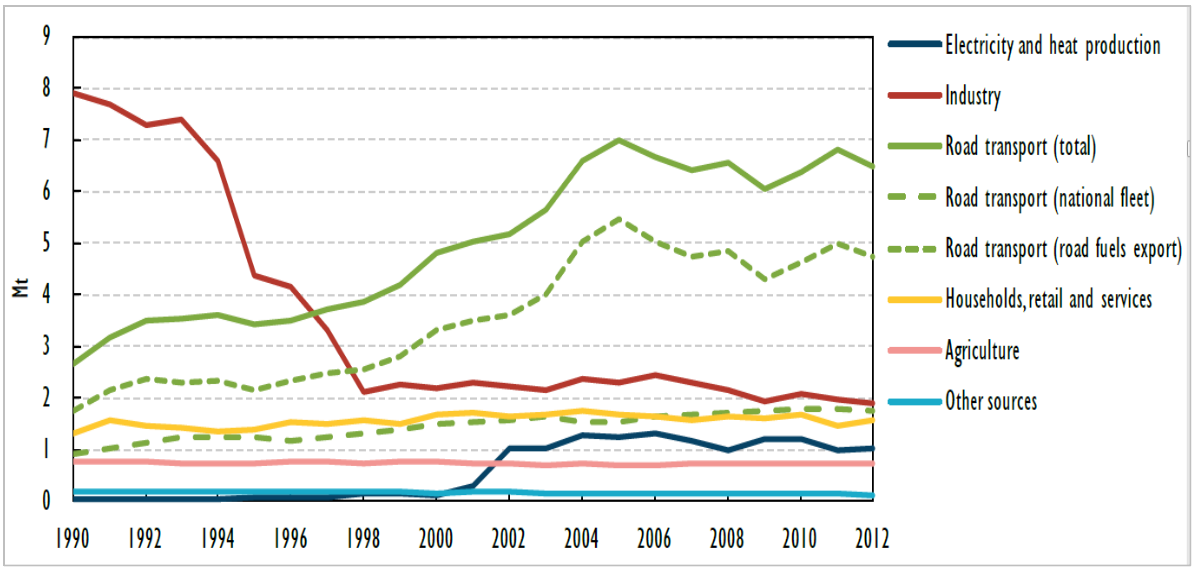
A long-standing way to motivate and incentivize better and wiser use of resources and preventing, reducing and minimizing negative externalities, is through including the social and environmental costs of these externalities in the cost of doing business and price of consuming goods and services. The European Commission DG Environment recently issued a 2200-page assessment, *Study on Assessing the Environmental Fiscal Reform Potential for the EU28*,

[303] WSA (2012) *Sustainable Steel, at the core of a green economy,* World Steel Association.
[304] Genet, Marcel (2012) EAF and/or BF/BOF: Which route is best for Europe? Platts' 8th Annual Steel Markets Europe Conference, May 21, 2012.

documenting the externalities and making recommendations on fiscal reforms that would motivate actions for greater energy and resource efficiency.

In the case of Luxembourg, greenhouse gas (GHG) emissions are a substantial externality in need of deep reductions. While significant reductions have been achieved by the industrial sector (e.g., the steel sector switching to energy and resource efficient electric arc furnaces that use recycled steel as feedstock, reducing coal emissions by 96%), emissions from the transport and power sector have soared. Transportation emissions have climbed 152% while the power sector experienced a rise in emissions of 3000%, due to constructing new and combined cycle natural gas plants and combined heat and power systems, as shown in Figure 25-2.

Figure 25-2: GHG Emissions by Sector 1990 – 2012



Source: Eunomia (2016), citing Source: International Energy Agency (2014) Energy Policies of IEA Countries - Luxembourg: 2014 Review, 2014, p.32.

Among EU Member States, Luxembourg has the highest level of GHG emissions per capita, and even among the highest worldwide, surpassing 24 tonnes of CO_2-eq per capita in 2012. Luxembourg is currently projected to exceed its 2020 emissions reduction target by 23 percent. A major recommendation by the OECD is for Luxembourg to reduce non-resident fuel consumption by means of raising the level of fuel taxation in alignment with EU averages. Cross-border commuters increased 350% between 1990 and 2012.

Luxembourg's tax rates for both fossil fuel products and electricity are significantly below EU averages, barely at the minimum level set in the Energy Tax Directive (ETD).

Diesel fuel excise fees are so low that they promote "fuel tourism" with non-residents fueling up in Luxembourg to take advantage of the low fuel prices. While this policy reaps the government tax revenues from non-residents (€745 million in 2015) it is having pernicious, unwanted side effects. Traffic congestion, noise, and exhaust pollution from the diesel fumes are a daily nuisance. Luxembourg incurs an annual energy trade balance deficit because of its need to import over 95% of petroleum and natural gas products. The steep rise in transportation CO_2 emissions is proving difficult to curtail. And Luxembourg has among the highest motorization rates in the EU, and well as among the EU's highest amount of time spent driving.

Another confounding policy is Luxembourg's vehicle registration fee, which is the same (€50) regardless of whether the vehicle is fuel sipping or diesel guzzling. Most European countries have implemented variable vehicle registration taxes/fees, based on fuel efficiency/inefficiency, fuel type, and level of CO_2 emissions. For example, the Netherlands (as well as Spain and Ireland) reduces registration fees for the most fuel-efficient cars. To register a Ford Fiesta costs €7,080, whereas a comparable priced Fiat 500 only incurs a €2,386 registration fee because it releases much lower CO_2 emissions. This similar policy practice in Ireland led to 90% of vehicle sales in lower-emission vehicle classes. Luxembourg's one fee fits all sizes, on the other hand, has no influence on the buyer's vehicle selection. Moreover, the Luxembourg tax regime in regards to company cars results in including a vehicle as in-kind benefits to employees' remuneration offers.

A key part of the 2016 *Study on Assessing the Environmental Fiscal Reform Potential for the EU28,* issued by the DG Environment of the European Commission, are recommendations reflecting the full costs of fossil fuels. The recommendations, summarized in Tables 25-4, 25-6 and 25-9, offer guidance for Luxembourg lawmakers and stakeholders.

Waste Streams

If there is an eye-opening reality to the loss of wealth in the linear economy, it is captured in the fact that 50 to 75 percent of all natural resources consumption becomes pollution and waste within 12 months.[305] Closing the loop, turning wastes into nutrients, reducing the need for virgin resources, and innovating through pursuit of biomimicry processes, are essential for expanding prosperity and wellbeing while collapsing waste and pollution.

[305] Matthews, Emily *et al* (2000) The Weight of Nations, http://www.wri.org/

Plastics

50% of plastics are disposed immediately after a single-use application, notably packaging, agricultural sheets and many consumer items. Plastics have grown 8.7% year after year since 1950, now amounting to nearly 300 million tons per year. The cost to the planet's degraded natural capital alone exceeds $75 billion per year. Following the current trend, petrochemical-based plastics are projected to account for 15 percent of the global carbon budget by 2050.[306]

CHALLENGE	PLASTIC	RELEVANT STAKEHOLDER	CAUSE	SOLUTION	STAKEHOLDERS
Access to feedstock	Recycled plastic	Recyclers/ manufacturers	Low perceived value of plastic	Consider 'true pricing' – monetizing externalities of plastic productio, consumptio and disposal	All
			Low collectio of plastic at end-of-use	Producer responsibility legislatio	Policy makers
				Improved access to recycling facilities/ curb side collectio	Policy makers
				Direct takeback of product – taking ownership of recovery	Retailers/ product manufacturers
	Biopolymers	Plastic manufacturers	Large scale plant matter from responsible sources	Incorporate industrial waste product – such as lignin, waste from pulp and paper sector.	Investors Academics/Researchers
Quality of end product (real)*	Biopolymers	Plastic manufacturers	Some bioplastic are reported to be inferior in some qualitie	Contined innovatio and development	Investors Academics/Researchers
	Recycled		Low quality feedstock can jeopardize quality in end product	Improve design for recycling/reuse	Original product and plastic manufacturers
Financial issues	Biopolymers and recycled	Recyclers/ manufacturers	Cheap oil commodity prices	Raise awareness of other financial benefit – stability of feedstock, brand value, protectio against future legislatio	All
	Recycled		Low volumes of processed material	Develop infrastructure to achieve economies of scale at each step of value chain	
Market demand	Biopolymers and recycled	Recyclers/ manufacturers	Distrust of benefit claims	Avoid greenwashing by ensuring benefit of product is scientifically and robustly calculated. Use a holistic assessment that considers potentia trade-offs.	Academics/Researchers Manufacturers (plastic and product)
			End customer not aware	Educate end consumers of the benefit of sustainable plastic to help drive demand	NGOs Policy makers
			Quality of end product (perceived)	Improved marketing and awareness raising, as well as contined development where issues do exist	Policy makers Manufacturers
			Higher costs of plastic	By improving technical issues faced in the above issues, cost of productio of sustainable plastic will be reduced, allowing for more competitive end pricing also.	All

Source: Trucost (2015)[307]

[306] Trucost (2016) Scaling Sustainable Plastics Solutions to drive plastics towards a circular economy, with Ocean Recovery Alliance, April 2016.

[307] *Ibid*., Trucost (2016).

Sanitation and Wastewater Treatment

As mentioned in the TIR Strategy Study Food chapter, Carole Dieschbourg, the Minister of the Environment, reported in 2015 that more than 70% of Luxembourg's surface water may not comply with the EU's 2015 targets for chemical and biological quality (EU Water Framework Directive). Roughly one-tenth of the below ground monitoring points indicated nitrates exceeded concentration limits. In shifting from the conventional linear model to a circularity model, Luxembourg's scores of towns and communities with small population sizes could pursue ecologically sustainable, modular, distributed wastewater treatment systems. The innovations in this field are fast evolving, with the following chart indicative of the range of approaches.

Wastewater treatment options

	Technology	Design criteria		Space demand	Energy demand	Nitrogen removal	Hygienic quality in the effluent	Removal organic matter	Advantages	Drawbacks
		m^2/PE	m^3/PE		kWh/PE/year					
Intensive treatment	**Activated sludge plant**	0.2	0.5	low	40	good	elimination by factor 10-100	> 75% COD	good elimination of all pollutants (SS, COD, N, P)	relatively high capital and operation costs, sensitive to hydraulic and pollutant overload, energy intensive, high technical know-how required, high quantities of sludge to be treated and disposed
	Trickling filter, rotating disc contactor	0.04-0.18	0.07-0.25	low	12	partly	factor 10-100 elimination	> 75% COD	simple operation requiring less maintenance and monitoring, lower sensitivity to load variations and toxins	rather high capital costs, large size structure for N removal necessary
	Anaerobic plant followed by further treatment		2.5	medium	use of biogas	little	elimination by factor 10-100	> 75% COD	energy recovery of biogas	hig capital costs, effluent must be further treated, high technical know-how required, difficult in cold winters, stabilized sludge
Extensive treatment	**Constructed wetland (horizontal flown)**	5	6	high	only pumping	little	elimination by factor 10-100	> 75% COD	low capital costs and simple operation, minimum sludge management	limited denitrification
	Constructed wetland (vertical flown)	3.5-4	3		only pumping	partly	elimination by factor 10-100	> 75% COD	low capital costs and simple operation, minimum sludge management	limited denitrification
	Waste stabilization pond system (natural pond)	>11		high	only pumping	partly	elimination > factor 1000	> 75% COD	low capital costs and simple operation	high evaporation rate, quality of discharge varies according to season
	Aerated pond		3 + 1	medium - high	> 10 (for aeration)	partly	elimination > factor 1000	> 75% COD	low capital costs and simple operation	high evaporation rate, quality of discharge varies according to season

Source: Wendland and Albold (2010)[308]

[308] Wendland, Claudia and Andrea Albold (2010) Sustainable and cost-effective wastewater systems for rural and peri-urban communities up to 10,000 population equivalents, Guidance paper, Women in Europe for a Common Future, http://www.wecf.eu/.

According to Eurostat, half of Luxembourg's solid waste was either landfilled (17%) or incinerated (33%). Luxembourg exported 172 kg per capita of hazardous waste in 2013, the highest of all European nations, followed by Belgium, Ireland and the Netherlands.

The EU's 2015 updated legislative proposals on waste established specific targets for waste reduction, setting out robust long-term stretch goals. Among the targets include:

- Recycling 65% of municipal waste by 2030;
- Recycling 75% of packaging waste by 2030;
- Binding landfill target to reduce landfill to a maximum of 10% of municipal waste by 2030;
- Ban on landfilling of separately collected waste;
- Promotion of monetary and fiscal instruments to discourage landfilling;
- Simplified and enhanced definitions and harmonized calculation methods for recycling rates throughout the EU;
- Concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material;
- Incentives for enhanceing recovery and recycling operations (e.g., for packaging, batteries, electric and electronic equipments, vehicles).

Most of of these initiatives are focused on reducing "less bads" generated by the linear processes of the Second Industrial Revolution. The expansion of the Third Industrial Revolution is predicated on wastes being largely prevented through whole systems integrated design, combined with any remaining wastes used as nutrients embedded in closed loop processes during a product's lifespan. Closed loop processes encompass every facet and aspect of economic and social activity.

Biosphere Valley – Rewilding Natural Landscapes

The Internet of Communications, Internet of Renewable Energy, and Internet of Mobility and Logistics created by the Silicon Valleys of the world are essential features of the Third Industrial Revolution. They necessarily operate within, and are fully dependent upon, the planet's biosphere, that thin layer surrounding the earth and vertically stretching up 19 kilometers into space. The health and wellbeing of humanity and the sustainability of the global economy are intimately dependent upon the biosphere. There are a myriad of complex social-ecological linkages ceaselessly occurring, embedded within and throughout the world's Biosphere Valleys.

Regional and national Biosphere Valleys, integrating rewilded nature corridors into the socio-ecological fabric enhance important long-term qualities such as resilience, adaptability, vitality, anti-fragility, and vigor. These qualities hold current citizens in good stead, while also acting on our moral responsibility to maintain a healthy planetary biosphere for the many generations to come.

The Third Industrial Revolution is poised to trigger exponential growth in world economic productivity, while at the same time greatly diminishing the immense biosphere impacts caused by First and Second Industrial Revolution technologies. Rewilding of biosphere valleys provides the assurance and insurance that these social-ecological processes will sustain and maintain flourishing life on earth far into the future.

Civilizations over the ages largely ignored maintaining the integrity of the biosphere, often to their peril. Archeological research has uncovered repeated collapses of earlier societies, invariably due to overusing and severely degrading their biosphere endowment.[309,310] Earth satellite imagery reveals Humans Appropriate nearly 40 percent of the global terrestrial plant Net Primary Production (HANPP); and more recent satellite mapping indicates "75% of the planet's land surface is experiencing measurable human pressures."[311] Expropriation of the land surface Net Primary Production, along with the soaring rates of marine and freshwater aquatic species die-off from overfishing the oceans, has driven up the current rate of species extinction to 1000 times faster than the natural background rate. With human population and resource consumption continuing to expand, it is estimated that the remaining "available" terrestrial NPP amounts to only 10 percent (when unproductive and remote lands, plus underground NPP like roots, are removed from the total).[312]

There are further risks to biodiversity and natural habitat loss as the global economy phases out fossil fuels. The historical consumption of Net Primary Production (NPP) for satisfying energy demands was replaced in the first and second industrial revolutions by mining underground

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[309] Tainter, Joseph (1990) The Collapse of Complex Societies, Cambridge University Press.

[310] Butzer, Karl W. (2012) Collapse, environment, and society, *Proceedings of the National Academy of Sciences USA*, PNAS, March 6, 2012, vol. 109, no. 10, http://www.pnas.org/content/109/10/3632.full.

[311] Venter, Oscar, Eric W. Sanderson, Ainhoa Magrach *et al*. (2016) Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation, *Nature Communications*, August 23, 2016, 7:12558, http://www.nature.com/articles/ncomms12558.

[312] Running, Steven W. (2012) A Measurable Planetary Boundary for the Biosphere, Science 337:1458; DOI: 10.1126/science.1227620

fossil fuels. The immense economic growth has come with the cost of unleashing catastrophic threats of climate destabilization. This, in turn, has generated a revival in mass production of bioenergy, threatening a far greater consumption of the Earth's remaining Net Primary Production. The risks to biodiversity and ecosystem services becomes clear when we recognize that satisfying the world consumption of fossil fuels with bioenergy substitutes would consume more than 400 times the planet's entire NPP.[313]

World-renown biodiversity scientist, Harvard Professor E.O. Wilson, exhorts humanity in his recent book, *Half Earth, Our Planet's Fight for Life*:

> *If biodiversity is to be returned to the baseline level of extinction that existed before the spread of humanity, and thus saved for future generations, the conservation effort must be raised to a new level. The only solution to the "Sixth Extinction" is to increase the area of inviolable natural reserves to half the surface of the Earth or greater.*

It has taken more than a century to set aside about 13% of Earth's land surface into wilderness reserves, nature parks, and protected areas.[314] Oceans and coastlines, already suffering some of the most damaging consequences (40% of the planet's coral reefs are dead, including 80% in the Caribbean, and over 50% of the Great Barrier Reef now dead with 95% threatened with permanent loss), have not received as much protection. Just 3.3% of the world's oceans and 7% of coastal areas are protected areas.[315] Some nations have pursued protection of significantly higher percentages of land surface. The ten top nations have set aside 40 to 60+ percent of their lands in bioreserves and conservation.[316] A large fraction of the nature parks unfortunately are not well protected; half of them are being exploited due to lax or absent enforcement.[317] Most problematic is the fact that nine out of ten of the planet's classified threatened floral and faunal species are located mainly outside existing protected zones.[318]

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[313] Dukes, Jeffrey S. (2003) Burning Buried Sunshine: Human Consumption of Ancient Solar Energy, Climate Change, 61: 31–44, Kluwer Academic Publishers.

[314] Dudley, Nigel, Liza Higgins-Zogib, Marc Hockings, Kathy MacKinnon, Trevor Sandwith, Sue Stolton (2011) National Parks with Benefits: How Protecting the Planet's Biodiversity Also Provides Ecosystem Services, Solutions, vol 2, issue 6, http://www.thesolutionsjournal.com/node/1008.

[315] Boonzaier, Lisa and Daniel Pauley (2016) Marine protection targets: an updated assessment of global progress, Oryx, 50(1), 27–35, Fauna & Flora International doi:10.1017/S0030605315000848.

[316] World Atlas (2013) Countries With The Most Protected Lands (Percentage Of Area As Reserves), http://www.worldatlas.com/articles/countries-with-highest-percentage-of-protected-reserve-lands.html.

[317] Laurence, William, D. Carolina Useche, Julio Rendeiro, Margareta Kalka, Corey J. A. Bradshaw, Sean P. Sloan, Susan G. Laurance, Mason Campbell et al. (2012) Averting biodiversity collapse in tropical forest protected areas, Nature, vol. 488, September 13, 2012.

[318] Nigel Dudley and Jeffrey Parish (2006) Closing the Gap. Creating Ecologically Representative Protected Area Systems: A Guide to Conducting the Gap Assessments of Protected Area Systems for the Convention on Biological Diversity. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 24.

To its great credit, Luxembourg has nearly tripled its terrestrial protected area, from roughly 12% in 1990 to 35% as of 2014.[319] This goes well beyond the international target set by the Convention for Biological Diversity of protecting at least 17% of terrestrial habitats by 2020.[320]

It is important to understand that the principle of circularity does not simply extend from the extraction of resources from the environment and the recycling of used products back into the environment. There is an increasing awareness of the need to properly nurture the 19 kilometers – from the stratosphere to the water – that makes up a country's biosphere zone. The recycling of used materials back into Luxembourg's natural environment, therefore, needs to go hand-in-hand with stewarding nature's circular flows that allow the biosphere to flourish. A rejuvenated biosphere, in turn, provides the sustenance to maintain a sustainable quality of life for present and future generations in Luxembourg. With its current commitment to maintain 35% of its landmass as protected space, Luxembourg can serve as an exemplary rewilding model for the rest of the European Union.

There are roughly 375 identified faunal species of amphibians, birds, mammals and reptiles, and more than 1,250 floral species of vascular plants in Luxembourg. None are endemic to Luxembourg (indigenous to the nation), but many are endemic to Europe. Roughly 2% of the species are threatened with extinction.[321] According to the IUCN's Red List assessment of Europe's 6,000 species, roughly 12% are located in Luxembourg (695), with 2% listed as threatened.[322]

The 2050 European Union Biodiversity Vision is far more challenging to achieve and sustain. According to the mandate, "the ecosystem services it [the Biosphere] provides – its natural capital – are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided."[323]

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[319] World Bank (nd) Terrestrial Protected Areas (% of total land area), http://data.worldbank.org/indicator/ER.LND.PTLD.ZS.

[320] UNEP (nd) Target 11 - Technical Rationale extended (provided in document COP/10/INF/12/Rev.1), Quick Guide (Target 11), Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity, Strategic Plan for Biodiversity 2011-2020, including Aichi Biodiversity Targets, Convention on Biological Diversity, UN Environment Programme, https://www.cbd.int/sp/targets/rationale/target-11/.

[321] Mongabay.com (na) Luxembourg Forest Statistics, http://rainforests.mongabay.com/deforestation/archive/Luxembourg.htm.

[322] IUCN (2013) Luxembourg's biodiversity at risk, A call for action, May 2013, European Red List, International Union for the Conservation of Nature, Global Species Programme, http://www.iucnredlist.org/europe.

[323] CBD (na) The 2050 EU Biodiversity Vision' National Biodiversity Strategy and Action Plans (NBSAPs), Convention for Biological Diversity, https://www.cbd.int/nbsap/about/targets/eu/.

Climate destabilization is the key threat of catastrophic change. Humans have become a planetary volcanic force – releasing the greenhouse gas (GHG in carbon-dioxide equivalents, CO_2-e) emissions every 10 hours equivalent to the 1992 Mount Pinatubo volcanic eruption. Failure to halt these CO_2-e emissions will result in the equivalent of 90,000 human-triggered volcanic explosions this century. CO_2-e directly increases the Earth's temperature, as well as causing water vapor to increase in the atmosphere. Water is another GHG, which results in further raising the global temperature.[324] Scientists estimate each 1 degree Celsius rise in global temperature activates 7 percent more water vapor in the atmosphere.

Climatologists calculate that this additional water vapor leads to a feedback loop doubling the amount of warming directly caused by CO_2. That is to say, a 1°C rise triggered by CO_2 will cause the global temperature to go up another 1°C as result of the increased water vapor. Humanity's current emissions trajectory is projected to increase global temperature by 5 to 7 degrees Celsius this century, injecting 35 to 50 percent more moisture into the atmosphere. The 1-degree C rise already occurring has unleashed a costly, continuous series of local and regional catastrophic weather patterns (e.g., numerous 1-in-500-year floods, droughts, wildfires, severe storms, recurring within months or several years). The one certainty about future weather is it will be filled with uncertainty and the increasing frequency of catastrophy-related weather disasters.

Herein lies the importance of rewilding; biosphere valleys augment resilience to deal and cope with climate-triggered catastrophic events. Rewilding, as a protected area design approach, emerged over the past half century from ecological research in half a dozen field research and scientific investigative disciplines.[325]

It is not currently known how much of Luxembourg's land set-asides constitutes comprehensive rewilding practices. But as E.O. Wilson and scores of scientists have argued, rewilding is an imperative worldwide. Undertaking rewilding in only a few localities, or implementing half-hearted measures, is inadequate. Just as a circular economy will only fully function when implemented by most localities in the global economy, so is the case with rewilding. Indeed, rewilding undertaken mainly by industrialized nations will have negative consequences if it results in fulfilling the demand for goods by shifting production and resource consumption to

[324] Chung, Eui-Seok, Brian Soden, B. J. Sohn, and Lei Shi (2016) Upper-tropospheric moistening in response to anthropogenic warming, *Proceedings of the National Academy of Sciences USA*, 10.1073/pnas.1409659111, PNAS August 12, 2014 vol. 111 no. 32:11636-11641, http://www.pnas.org/content/111/32/11636.

[325] Soulè, Michael and Reed Noss (1998) Rewilding and biodiversity conservation as complementary goals for continental conservation, Wild Earth 8: 18-28.

biodiversity-rich developing countries, threatening acceleration of the destruction of intact wilderness regions.[326]

Interactions with other pillars

Industry

First, companies can contribute to the switch from fossil or nuclear energy to renewable energies. One of the first steps should be to convert current heat losses into a usable energy source for further use. Industry is a key actor in the circular economy as the highest impact is created if products are designed for continuous cycles. Beyond the technical issues, the actual business model will have to be adapted toward a new approach: product as a service.

Finance

The finance sector often plays the role of business enabler. The development of new business models requires different views and approaches towards financing. Circular economy projects might need higher initial investments but will have important returns in the longer term. The funding sector might be interested in investing in 'circular' companies, creating positive impacts. Therefore, it will be important for the finance sector to understand the underlying circular approach. Tools for evaluating how circular a business really is, will be needed. The financial industry should investigate how the blockchain technology can be used in a large range of applications, where data privacy and transparency are required. Virtual currencies could help to make sharing platforms work.

Mobility

Reverse logistics, car/truck pooling, multimodal transport, and driverless and electric and hydrogen fuel cell vehicles, are commonly identified areas that need to be pursued in ushering in the Mobility Internet. Electric cars don't need fossil energy (if the electricity is produced by

[326] Lambin, Eric F. and Patrick Meyfroidt (2011) Global land use change, economic globalization, and the looming land scarcity, Proceedings of the National Academy of Sciences USA, vol. 108, no. 9, March 1, 2011, http://www.pnas.org/cgi/doi/10.1073/pnas.1100480108.

renewable energy) and electric cars could be used for distributed energy storage. But the current lithium-ion batteries are not yet designed for continuous loops. Therefore, the battery technology should not only be looking at how to increase the energy storage density, but also how to recover 100% of the used materials at a high quality. The research for new concepts (for example fuel cell) should continue. Driverless vehicles will contribute to significantly reducing the logistics (and reverse logistics) cost, enabling the development of more continuous material loops.

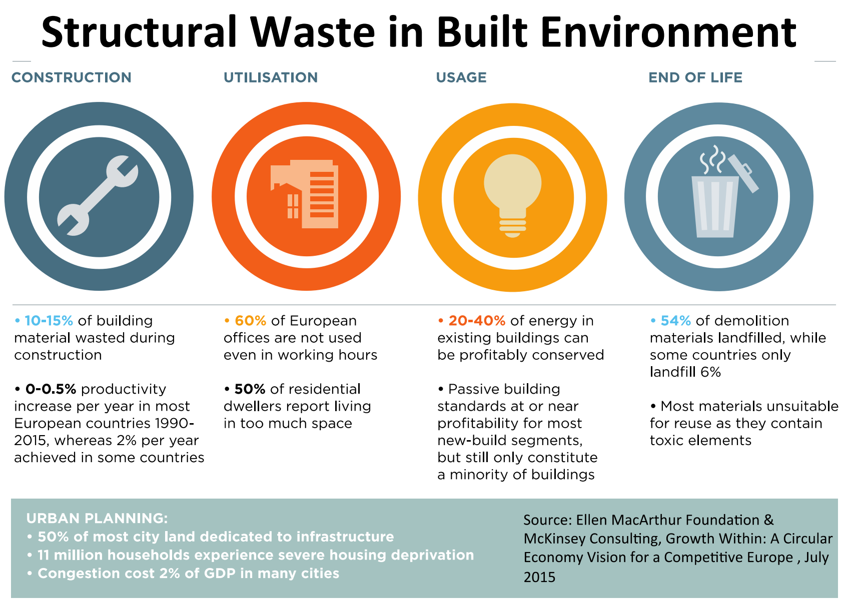
CIRCULAR ECONOMY: Mobility

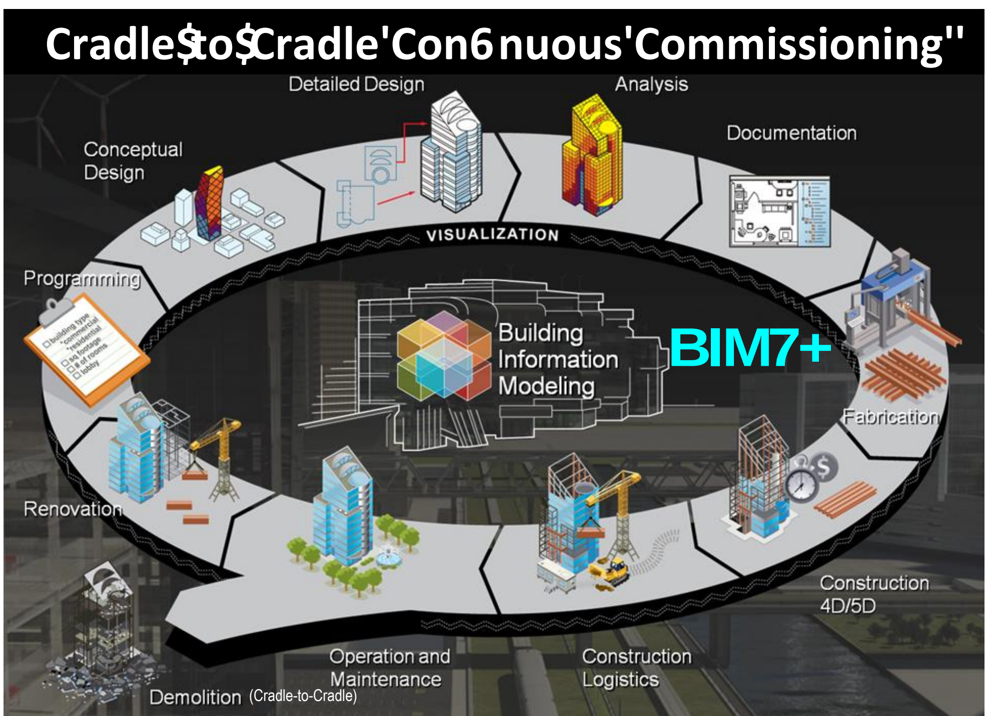
Implementation of Strategies

	CLOSING MATERIAL LOOPS (technical strategies)	CLOSING LIABILITY LOOPS (commercial/marketing strategies)
RESOURCE EFFICIENCY STRATEGIES		
Reduce the VOLUME of the resource flow	ECOPRODUCTS ▪ *Driverless vehicles* ▪ *Ultra-light BEVs* ▪ *Bikes/trikes* ▪ *Access via Smartphone*	ECOMARKETING ▪ *Car-sharing* ▪ *Ride-sharing* ▪ *Shared-car ownership*
Reduce the SPEED of the resource flow	REMANUFACTURING ▪ *Refurbished vehicle* ▪ *Reused components* ▪ *Recycled metals & composites*	REMARKETING ▪ *de-curement services (used & discard exchange)* ▪ *new products from waste*
Reduce the VOLUME and SPEED of the resource flow	SYSTEM SOLUTIONS ▪ *IoT/IoS/IoN (Things/ Services/Networks)* ▪ *Picogrid BEVs linked to Nanogrid buildings*	SYSTEMIC SOLUTIONS ▪ *selling results instead of goods* ▪ *selling services instead of goods*

Buildings

Integrated and integral building design should aim for buildings that are energy positive and that act as material banks (BIM-process). In addition, they are connected in multiple ways to the Internet and will generate large sets of data (i.e., instant information about material flow through a building). New urban collaborative and sharing concepts should be promoted (for example, urban farming on rooftops).





Neil Calvert, "Why We Care About BIM...," Directions Magazine, Dec. 11, 2013, http://www.directionsmag.com/articles/why-we-care-about-bim/368436

Food

Local and organic production of food is certainly a circular approach. In addition, the sector should focus on how to close the biological loop by bringing back the nutrients to the soil. The farmers should look at how they can create additional positive impacts like, for example, storage of carbon in the soil, or working the fields in such a way that high quality drinking water can be obtained. Agriculture will also need to evolve into new bio-based products like *Miscanthus* spp. for the construction industry.

CIRCULAR ECONOMY: Food

Implementation of Strategies

	CLOSING MATERIAL LOOPS (technical strategies)	CLOSING LIABILITY LOOPS (commercial/marketing strategies)
RESOURCE EFFICIENCY STRATEGIES		
Reduce the VOLUME of the resource flow	**ECOPRODUCTS** ▪ *Local organic gardens* ▪ *Local organic farms* ▪ *No petrochemical fertilizers, biocides, fuels*	**ECOMARKETING** ▪ *CSA (Community-Supported Agriculture)* ▪ *LuxBrand EBO foods*
Reduce the SPEED of the resource flow	**REMANUFACTURING** ▪ *Food waste to nutrient* ▪ *Solar/Wind powered electric farm equipment*	**REMARKETING** ▪ *Composting* ▪ *biogas* ▪ *Composite Graphite* ▪ *Hydrogen fuels*
Reduce the VOLUME and SPEED of the resource flow	**SYSTEM SOLUTIONS** ▪ *IoT/IoS/IoN (Internet of Things/Services/Networks)*	**SYSTEMIC SOLUTIONS** ▪ *selling results instead of goods* ▪ *selling services instead of goods*

Energy

Making better use of the wasted heat is one possible approach to reduce our dependence on fossil fuels. Onsite and distributed energy systems based on renewable energy sources are a key part of a circular economy. Highly flexible pricing models (reflecting the actual demand/offer situation) could enhance the shift to distributed energy production and accelerate this transition. The new technical solutions for renewable energy production and storage should also be designed for continuous loops.

CIRCULAR ECONOMY: Energy Services

Implementation of Strategies

	CLOSING MATERIAL LOOPS (technical strategies)	CLOSING LIABILITY LOOPS (commercial/marketing strategies)
RESOURCE EFFICIENCY STRATEGIES		
Reduce the VOLUME of the resource flow	ECOPRODUCTS ▪ *end-use efficiency* ▪ *wind & solar power* ▪ *No fuels, water, emissions, pollution, minimal land*	ECOMARKETING ▪ *Shared utilization of goods via cooperatives* ▪ *Selling utilization instead – delivery of services onsite*
Reduce the SPEED of the resource flow	REMANUFACTURING ▪ *reusable/recyclable steel/ aluminum/composites* ▪ *Co-located food growing, or rooftops and BIPV*	REMARKETING ▪ *Dismantle/disassemble* ▪ *away-grading of goods and components* ▪ *new products from waste*
Reduce the VOLUME and SPEED of the resource flow	SYSTEM SOLUTIONS ▪ *IoT/IoS/IoN (Internet of Things/Services/Networks)*	SYSTEMIC SOLUTIONS ▪ *selling results instead of goods* ▪ *selling services instead of goods*

Smart Economy

One way to improve the quality of our raw material usage is to improve the amount and quality available for each product. This represents a whole new area of opportunities for implementing a smart economy, based on the Internet of Things and fully automated processes (for example: data exchange, logistics tasks). Like the other pillars, the new infrastructure needs to be designed for disassembly and re-use as well

CIRCULAR ECONOMY

Implementation of Strategies

	CLOSING MATERIAL LOOPS (technical strategies)	CLOSING LIABILITY LOOPS (commercial/marketing strategies)
RESOURCE EFFICIENCY STRATEGIES		
Reduce the VOLUME of the resource flow	ECOPRODUCTS ▪ *dematerialized goods* ▪ *multifunctional goods*	ECOMARKETING ▪ *Shared utilization of goods* ▪ *Selling utilization instead*
Reduce the SPEED of the resource flow	REMANUFACTURING ▪ *long-life goods* ▪ *product-life goods* ▪ *cascading, cannibalizing*	REMARKETING ▪ *de-curement services (used & discard exchange)* ▪ *away-grading goods/components* ▪ *new products from waste*
Reduce the VOLUME and SPEED of the resource flow	SYSTEM SOLUTIONS ▪ *engineering systems*	SYSTEMIC SOLUTIONS ▪ *selling results instead of goods* ▪ *selling services instead of goods*

Source: Stahel (1997)[327]

Prosumers

In a distributed future, where a more effective use of resources is the norm, the consumer acts more and more as a producer as well (energy, small service or equipment provider and even investor). This requires a significant change of mindset for our society. In a circular economy the access to a service is considered to be more important than the possession of a product. This social and technological revolution requires a different education system that can explain the reasons why we need to change and provide the right knowledge base for the next generation.

[327] Walter Stahel (1997) "The Functional Economy: Cultural and Organizational Change." National Academy of Engineering, The Industrial Green Game: Implications for Environmental Design and Management, National Academies Press, 1997, doi:10.17226/4982

PROPOSALS

1 Business Model Innovation

1.1 Develop an Internet platform and LuxLoop app for the purchase, exchange and distribution of secondary sourced materials (short term example: excavation waste). Create product descriptions, procedures and criteria. Establish quality assurance for the information going into the database. Implement the required legal framework. Develop the LuxLoop mobile App for easy exchange of technical data, specifications, availability and quantity. This is key for raising awareness about the circular economy.

1.2 Pursue a 100% renewable power economy for Luxembourg by 2050. The precipitous decline in the cost of wind and solar power should be seen as an EU regional and global market potential. By making a national commitment, Luxembourg positions its leading businesses, research centers, and financial sector to accelerate their learning and experience curves by making the transition and transformation of the current predominantly fossil and nuclear powered grid to a 100% renewable one. Luxembourg has a well-integrated electricity system, with interconnectors enabling power exchanges between wholesale operators. The Fraunhofer Institute has performed an economic-engineering assessment for a 100% highly energy efficient, renewable-powered Luxembourg economy.

1.3 Engage the farming community in producing wind and solar PV power as "cash crops." Of the nation's total land area of 2,590 km^2, roughly 52.6%, or 1,310 km^2 (131,000 hectares), consists of agricultural lands. The opportunities for transitioning to Renewable Smart Power could provide a valuable *additional* revenue stream for rural farmers. As an example, consider satisfying 22% of Luxembourg's total energy needs through farm-based wind power. It would involve harnessing 8.6% of the nation's technical wind potential, which could be accomplished with 319 installed turbines, each 5 MW rated power (total of 1,594 MW nameplate capacity). The spacing area would occur over 202 km^2 (roughly 15% of agricultural land area, of which 90+% would still be available for farming). The estimated LCOE (levelized cost of electricity) is estimated at €cents 7/kWh. The upfront capital cost (in 2016€) is estimated at €1.89 billion, with an energy simple payback of 4.3 years. A farm cooperative could be established to carry out this opportunity for the farming community.

1.4 **Promote agricultural, local and organic products.** There are existing organic grocery stores selling regional products in Luxembourg. There are also local organic production initiatives: Naturata, Oikopolis. What is needed is greater support for the development of expanded organic agriculture, resulting in positive impacts generated by the farmers. This will require ongoing research combined with pilot projects to investigate potential positive impacts, for example chemical free areas, changes in yields, and soil carbon enhancement.

1.5 **Promote the Circular-Design of products and new business models.** Potential collaborators in circular design include the Design School CAD Wiltz and the FAB Lab (3D Laboratory) in Belval, Esch-Alzette. The EU ECO Design Directive – the REACH process – promotes circular design requirements at the EU level and offers financial support for specific R&D projects. Part of the mandate of the REACH program is to definine minimum design standards. Luxembourg should champion the expansion of the existing ECO design directive to include a circular approach. Circular design should be phased-in as a mandatory module in technical education and efforts should be made to attract design schools to Luxembourg.

1.6 **Promote new business models: Product-as a-service and circular supplies.** Some examples of product-as-a-service exist already in Luxembourg, e.g., agricultural machines and toys. Identify other products with potential to be shifted from traditional "buy and own" to "use as a service" and promote such transitions. Develop new business models and support pilot projects via specific national support programs (Fit 4 circularity). Provide financial support for this type of approach. Expand research in new IoT technologies (smart tags, low cost sensors, IoT tools and techniques, mobile apps) to help in the implementation of such a system. Promote public procurement that allows 'pay for performance' contracts. Revise tax system to give preference to 'usage' of a product versus the possession of a product at the moment when the purchasing decision is made.

2 Technical

2.1 **Develop nutrient recovery in wastewater treatment stations.** Promote segregation of problematic waste streams at the source. Establish pilot projects for extracting phosphates and support research for extraction of other nutrients, followed by large-scale recovery programs. Implement infrastructure to separate grey water and wastewater. Require all new wastewater treatment stations to recover phosphates.

2.2 **Pilot test blockchain technology to track circular economy inputs, throughputs, and outputs of supply chains and value chains of public institutions and private businesses**. Blockchain is a distributed ledger that encrypts transactions that are also auditable. Blockchain appears to be a useful tool for tracking, measuring and validating the flows of waste, pollution, and overall resource use. Blockchain could serve as the repository of metrics indicators in the circular economy.

2.3 **Support a collaborative innovation network (COIN) platform for designers, practitioners, and related professionals to interact, share and cultivate pathways for scaling up both skills and investment in circular product design and production which could facilitate greater re-use, remanufacture, repair and recycling.**

3 Regulatory

3.1 **Implement a taxation system that places the nation as the EU circular economy leader; or at least raise circularity to levels commensurate with the EU average**. A key part of the circular economy is internalizing the costs associated with externalities incurred during economic activities. Luxembourg embraces the principles of polluter pays and user pays. An innovative tax system motivates actions to innovate on the production side through resource efficiency improvements that cut costs, as well as motivating customers to purchase more energy and resource efficient products to lower costs. This systematic change aims at increasing the tax rate on material consumption, while incentivizing the re-use of high quality materials / components with lower taxes. The additional tax income should be used to lower the work related taxes in such a way that the total tax burden is not increasing. Luxembourg's current environmental taxes amount to 2% of GDP, down from the 2004 level of 3.03% of GDP. According to the January 2016 report on Environmental Fiscal Reform issued by the DG Environment of the European Commission, Luxembourg's current rate is among the lowest in the EU28: ranking 20th for overall environmental taxes as a percent of GDP, 24th for taxation of pollution and resources, and 25th for transport (excluding fuel).[328]

[328] Eunomia (2016) *Study on Assessing the Environmental Fiscal Reform Potential for the EU28*, January 2016, by Eunomia Research & Consulting Ltd for the DG Environment of the European Commission, http://www.eunomia.co.uk/reports-tools/study-on-assessing-the-environmental-fiscal-reform-potential-for-the-eu28/

4 Public Policy

4.1 **Provide financial incentives to facilitate development and implementation of an Internet platform and LuxLoop app [described in 1.1 above] for the purchase, exchange and distribution of secondary sourced materials.** The funding is needed in order to develop the required information, secure storage space on data centers, engage technical know how to build and maintain the database, and to assemble a communication team that explains and promotes the “Luxloop” App.

4.2 **Foster the use of "wasted" energy, continue improvements in energy efficiency, and expand the use of renewable power** [see 1.2 above]. Develop and maintain a ‘re-usable energy source/flows’ inventory map. The European Energy Directive (2012/27/EU)[329] already requires large consumers to know their energy losses, and the Luxembourg National initiative, Pact climat (http://www.pacteclimat.lu/fr for municipalities) promotes energy consumption data collection and local actions to reduce the energy bills. Integrate apps into the inventory map that enable calculating the cost of capturing re-usable energy for additional purposes, as well as links to case examples of where this has been done, experts who can be contacted, and financial incentives available from different entities, e.g., EU, national, municipal, utility, third parties. Determining the cost-effectiveness of harnessing re-usable energy should be compared to upgrading the existing operation with more efficient and potentially cost-saving electrification alternatives, which could lead to removing the existing thermal conversion process (e.g., as the steel industry has done in replacing Blast Furnaces/Basic Oxygen Furnaces with Electric Arc Furnaces).

4.2.1 Develop reusable energy pilot projects, for example, greenhouses on top of industry roofs.

4.3 **New economic zone developments should take into account the expected valorization of energy losses and renewable energy production during the planning phase and design of new infrastructure.** Traditional and conventional planning and design layouts have typically overlooked or ignored synergistic opportunities that realize both capital and operating expenditures. Examples include: layout of adjacent businesses for taking advantage of cascading energy processes (a model case of an industrial symbiosis network

[329] CEN/CENELEC (2015) European Standards for Energy Audits: helping companies to comply with requirements of the EU Energy Efficiency Directive, European Committee for Standardization/ European Committee for Electrotechnical Standardization, July 9, 2015, http://www.cencenelec.eu/News/Press_Releases/Pages/PR-2015-06.aspx

is Denmark's Kalundborg Eco-Industrial Park); integrating safe pedestrian and bicycle paths, as well as convenient transit interconnection points; spatial orientation and shaping of buildings to optimize energy efficiency and solar gains, while avoiding shading and ensuring each building has solar access; and designing surrounding landscapes and street layouts that take advantage of the diurnal and seasonal microclimate conditions (e.g., avoid creating artificial wind tunnels, promote breezeways, include shady walkways with tree canopies, as well as sunny areas and wind breaks). There are open source software programs available for performing these myriad tasks.

4.4 **Establish a national policy that integrates the development of a circular economy throughout Luxembourg's economic sectors.** Catalyzing the circular economy is, in a very fundamental way, a core part of Luxembourg's strong policy priority promoting a diversified, knowledge-intensive economy by taking advantage of IoT (HPC and CBA) tools and technologies. Just as smart buildings, smart grids, smart vehicles, and smart manufacturing all require continuous measuring and analyzing of Big Data to determine and ensure performance as designed, so is this the case with the energy and material flows constituting the circular economy. To avoid lost opportunities and seize unfolding opportunities, the circular economy should be recognized as a linked and vital component of advancing the interconnected digital Communication Internet, Renewable Energy Internet, Mobility and Logistics Internet, Buildings as nodes (and nanogrids), and the Internet of Things.

4.5 **Prioritize large-scale circularity initiatives in the industrial, commercial, and agriculture sectors.**

4.6 **Identify and remove the barriers and impediments currently limiting public procurement practices and incentives in government and public agencies from purchasing sustainable, green, resource efficient products and services.** Engage business firms to help identify and eliminate these barriers.

4.7 **Promote the establishment of material passports for every technical product.** Leverage the ongoing developments of the EU Horizon 2020-sponsored Buildings As Material Banks (BAMB), now underway with sixteen partners from eight European countries. The goal is to integrate circularity practices in the building sector, including reversible building design, as well as business model innovations, decision-making and management models, and policy propositions.[330]

[330] BAMB, Buildings as Material Banks, http://www.bamb2020.eu/about-bamb/.

4.8 **Establishment of a material examination office.** Creation of a national institute whose mission is the control and analysis of specific products in order to validate the quality of the used materials and to certify their technical nature. This institute should act independently and should not be subject to producers or suppliers. This office would also issue material passports.

4.9 **Material passports should be promoted through public procurement.** Material passports integrated with blockchain technology could provide continuous tracking of products. Material content and assembly methods would always be traceable, and enable taxation to be automated, depending on the final destination of the product. Minimum legal standards for healthy design and design for disassembly should be established and periodically reviewed, for inclusion in material passports.

4.10 **Promote energy network stability and cost savings through instant pricing and local energy storage.** Expand installation of smart meters, and implement a flexible short term energy pricing scheme which contributes to stabilizing the networks, saving money for both end-users and operators, supporting distributed production plants, and achieving the 100% renewable energy goal faster. Promote smart-controlled equipment for enabling participation in real-time demand response options. Support technical development of energy storage solutions that are re-usable. Support fully autonomous energy consumption by electronic devices and machines, connected to the Internet, and automated energy storage based on energy availability and short term provisions around local consumption and production.

4.11 **Through a public-private partnership, promote smart supply chains, intelligent assets, and standardized logistics container/tray pool.** Spread use of existing technologies (RFID, geo-localization) for high value items together with other information like usage, need for repair, and storage conditions (humidity/ temperature). Foster standardized packaging solutions for all local postal, parcel and logistic companies managed in a central pool. Develop a demonstration smart warehouse, that can easily be adapted to future needs and that detect material flows through the building. Develop low cost technologies to ensure tracking of goods, and packaging materials, and of transportation equipment for multiple industries (logistics, food, automotive suppliers, medical). Develop safe data transmission protocols (e.g., blockchain technologies).

4.12 **Promote sharing equipment and tools.** A number of local sharing initiatives exist. For example, dingdong.lu provides a sharing service for household items. "Maschinenring Luxemburg" rents large machinery to farmers. COMAT rents materials for the construction sector and for other industries and public institutions. Public authorities should promote a wide range of enterprises to allow families and businesses to share an array of items that are only needed on a short-term basis.

4.13 **Establish a new Commissioner on Rewilding to oversee already existing rewilded conservation areas.** Rewilding is based on trans-disciplinary, multi-disciplinary, and inter-disciplinary research, experiments, actions, and adaptations. It is an emergent scientific field of non-linear dynamics in complex systems that require adaptive management over time as new insights and findings from diverse fields of research and modeling indicate modifications are needed. A Commissioner on Rewilding is essential for ensuring a robust initiative *to protect, steward, and sustain Luxembourg's swath of the Planetary Biosphere.* Bringing together citizen stakeholders and experts from academia, business, and government, into a quadruple helix of knowledge innovation will be vital for fleshing out Luxembourg's unique rewilding opportunities and challenges.

4.14 **Partner with neighboring nations and the Pan European Ecological Network to implement transboundary rewilidng core areas and corridors.** Earth systems sciences, ecological network theory, and multi-level evolutionary framework analysis have each provided compelling insights and reminders that the biosphere is not constrained by political boundaries.[331] A fully effective rewilding initiative will require partnering with *other regions and* nations (given the vast span of many seasonally migratory species). The same TIR technologies will be essential for collecting, monitoring, and evaluating continuous streams of big data, and making informed judgments on adaptive management options.

5 Financial

5.1 **Shift taxes off of people and onto environmental pollution and emissions.** Taxing labor discourages expanding employment, while failing to fully tax environmental externalities removes incentives to reduce or eliminate pollution and emissions. Environmental taxes

[331] Schimel, David, Kathy Hibbard, Duarte Costa, Peter Cox, Sander van der Leeuw (2016) Analysis, Integration and Modeling of the Earth System (AIMES): Advancing the post-disciplinary understanding of coupled human–environment dynamics in the Anthropocene, *Anthropocene Journal*, March 2016, http://dx.doi.org/10.1016/j.ancene.2016.02.001.

in the EU have declined in recent decades, and now constitute 2.5% of EU GDP.[332] While environmental regulations have replaced some tax needs there remain greater opportunities. For example, a revenue-neutral carbon fee on all CO_2 emissions would incentivize increasing efficiency-productivity improvements and shifting to near zero-emission solar and wind power, while minimizing the impact by providing a tax return to citizens that left them financially whole.[333]

5.2 Modify the tax system to promote re-using of resources instead of using primary raw materials. Establish financial incentives promoting the use of secondary source materials as raw material, as well as financial incentives promoting eco-design / material selection / design for disassembly.

5.3 Establish a taxation system for the use of new resources in non-consumable products. A change in the tax system is required to shift purchasing perspectives from the linear "take-make-dispose" model to "retake-remake-reuse-reduce-recycle" circular model. The specifics should be fleshed out through a public-private task force that reviews the experience and evidence of how such tax systems are working in other nations, and makes recommendations for modifying Luxembourg's tax system.

5.4 Incentivize dismantable "zero emission" buildings. Luxembourg has already mandated that beginning in 2017 the passive house standard (Class A) will be required for new residential buildings.[334] In addition, financial incentives for energy positive housing, renewable energy production, and dismantable buildings should be implemented.

6 Educational

6.1 Promote new educational curricula that help student learn new aptitudes, skills and competences for circular product design and production.

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[332] Mathé, Milena, Gaëtan Nicodème and Savino Ruà (2015) *Tax Shifts*, European Commission, Working Paper No. 59, European Commission's Directorate-General for Taxation and Customs Union, October 2015.

[333] Komanoff, Charles (2016) Revenue-neutral Carbon Tax FAQ, Carbon Tax Center, http://www.carbontax.org/.

[334] Lichtmeß, Dr. Markus and Dr. Jens Knissel (2013) *Nationaler Plan Luxemburgs zur Erhöhung der Zahl der Niedrigstenergiegebäude im Rahmen der Richtlinie* 2010/31/EU vom 19. Mai 2010 über die Gesamtenergieeffizienz von Gebäuden (Neufassung) Luxemburg, Juli 2013, Gouvernement du Grand-Duché de Luxembourg Ministère de l'Economie et du Commerce extérieur Direction générale de l'Energie [National plan of Luxembourg for increasing the number of nearly zero energy buildings under Directive]

6.2 Promote the circular business approach with large-scale awareness campaigns. Currently, different initiatives are ongoing including the Fit4Circularity initiative; the Superdréckskëscht which provides information to companies and households; and the nearly three decade environmental fair of the Greater Region, Oekofoire. Local/regional transition networks exist: (Transition Minett). Large and medium size companies have an RSE [social and environmental responsibility] coordinator analyzing the positive and negative impacts of the company. Promote a new circular economy (CE) EU label. Use the 2017 CE event to make existing initiatives visible. Run a large-scale nationwide communication campaign to promote the idea that access to a product is cool and trendy, as well as promote the positive impacts created by a circular approach. Integrate CE training and competence as part of the Luxembourg education system in the primary and secondary schools, universities, and in lifelong learning programs. Propose products that can be labeled as circular (C.E. labeled) on an EU level. Establish a public procurement plan for purchasing an increasing percentage of CE certified products.

6.3 Encourage school systems to encompass contemporary topics like: Social and solidarity economy, circular economy and new (IoT) technologies. Currently, basic introduction training programs are developed for both primary and secondary school as well as for training professionals. Specific ITC courses exist but are not standardized. Going forward, develop classroom, online, and field training programs to educate teachers. Review current teaching programs for each school level. Run pilot projects in different schooling systems. Pilot lifelong teaching programs. Roll–out new concepts for the future.

7 RDI

7.1 Promote the development of Bio-based batteries through public-private partnerships. The government, Goodyear, and IEE of the Automotive campus in Bissen are currently providing state-of-the-art facilities to firms engaged in technical innovation of automotive components. Luxembourg is an ideal test bed for new developments of electric cars. Also underway is the joint project with Volvo Buses and ABB to engineer and commercialize electric and hybrid buses employing direct current (DC) fast charging systems based on open standards. A parallel joint effort should also be undertaken in the development of bio-based batteries: how to re-introduce them back into the biological cycle by initiating pilot projects and supporting research into battery solutions where all the components could be reused later on. Support research into storage solutions and seek to become the international expert for bio-based batteries and the build up of the recovery infrastructure.

7.2 **Develop bio based nano-composites, designed for easy disassembly.** A new nano-composite center was established in 2016, operated under the PEARL program and funded by the Luxembourg National Research Fund (FNR). Vigorous and sustained investment should be supported in the development of bio-based nano-composites that can be disassembled again in a safe way. Also initiate pilot projects, and promote new innovation with bio-based composites in the building sector. Strive to become the international expert center for bio-based nano-composites, and the worldwide leader for disassembly on a molecular level of composites.

7.3 **Support research programs for technological solutions and innovation in technologies for renewable energy, energy storage, and energy transportation**. Leverage the RDI already underway through EU initiatives, as well as in other nations and corporations. Given Luxembourg's leadership push in ICT/IoT technologies, as well as its financial prowess, examine how these two sectors can both take advantage of and build upon this larger pool of RDI, as well as promote commercial expansion.

7.4 **Public RDI and Private sector RDI need to align and leverage their efforts for advancing aggregate efficiency-productivity gains through HPC & BDA tools and technologies**. According the European Commission, Luxembourg leads the EU in public RDI scientific performance, whereas private sector RDI has declined well below the EU average, noting, "the volume of public sector research and innovation financed by businesses represents only 0.017 % of GDP compared with an EU average of 0.051 %." Part of the drop is due to the nation's shrinking industrial base. The largest sector of the economy, finance, does relatively little public RDI. Applied research is what firms need, and public research centers should collaborate with firms in the design of a mutually beneficial ecosystem of activities. The network and sharing platform of Luxembourg's EcoInnovation Cluster appears to be moving in this direction, with a quintuple helix knowledge network comprised of a myriad of business sizes and product lines, along with government agencies and other academic and research institutes.

7.5 **Perform a rewilding inventory of already existing lands and inland waters under conservation protection arrangements.** Determine the additional actions required for ensuring that already protected areas are being transitioned into rewilding structures and functions, and are sustained even as climate change dynamics unfold. This involves multi-faceted and multi-level research efforts to protect native floral and faunal species (above and below ground) that evolved during the Holocene (past 11,700 years).[335] The long-and-slow and short-and-fast temporal cycles historically occurring at different spatial dimensions in and between the diverse ecosystems of the biosphere are undergoing dramatic change due to climate destabilization. The data capabilities of TIR Internetization, digitization and AI technologies are central to achieving and sustaining effective rewilding efforts. The Big Data will have to be mined via complex socio-ecological systems-theory modelling to sustain local ecosystems in a rapidly changing climate.

[335] Bai, Xuemei, Sander van der Leeuw, Karen O'Brien, Frans Berkhout (2016) Plausible and desirable futures in the Anthropocene: A new research agenda, *Global Environmental Change* 39:351–362, http://dx.doi.org/10.1016/j.gloenvcha.2015.09.017.

PROSUMERS & SOCIAL MODEL

OVERVIEW

Co-Chairs Charles Margue and Serge Allegrezza, and the Luxembourg Prosumers & Social Model Working Group;

Michael Totten (Assetsforlife.net) and Jeremy Rifkin, TIR Consulting Group LLC

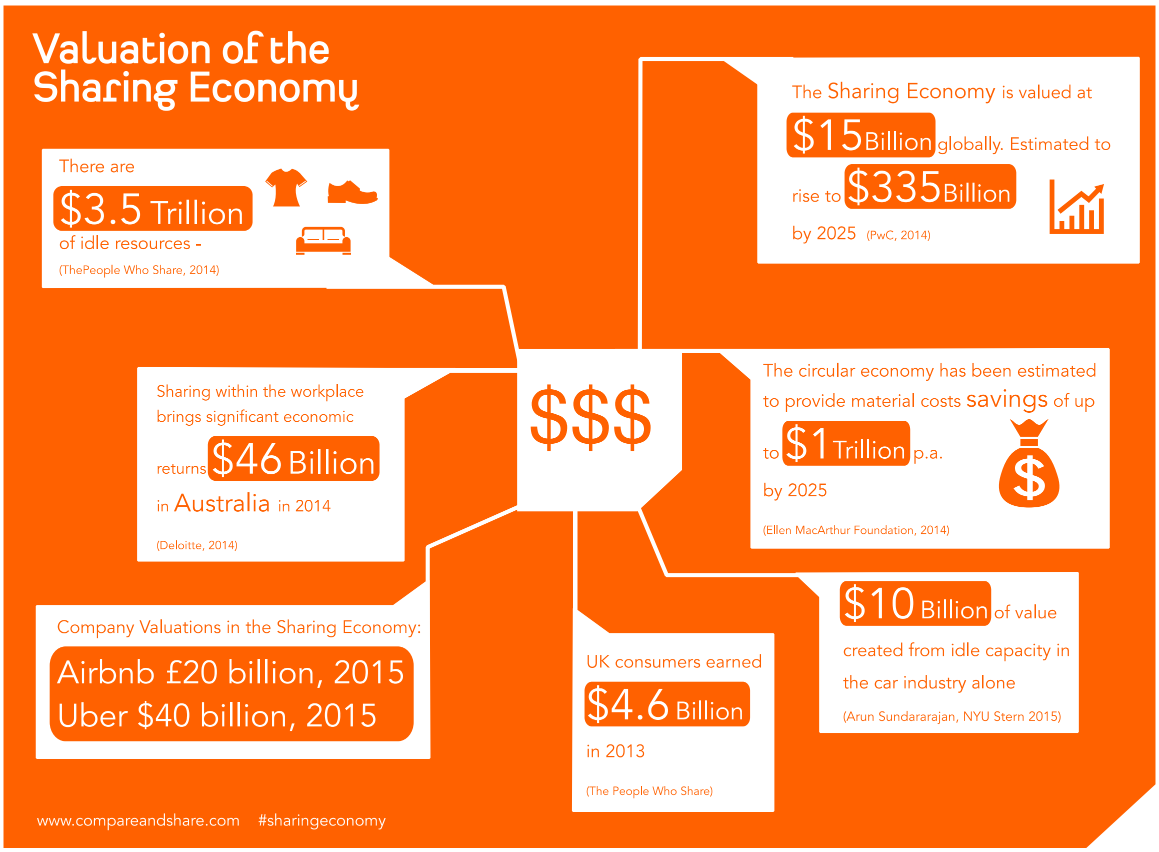
Capitalism is giving birth to a progeny. It is called the Sharing Economy on the Collaborative Commons. This is the first new economic system to enter onto the world stage since the advent of capitalism and socialism in the early 19th Century, making it a remarkable historical event. The Sharing Economy is already changing the way we organize economic life, offering the possibility of dramatically narrowing the income divide, democratizing the global economy, and creating a more ecologically sustainable society.

Like every parent-child relationship, the two economic systems generally cooperate but occasionally are at odds. And while the capitalist parent will need to nurture its child and allow it to mature, the child will also transform the parent in this unfolding relationship. We are already witnessing the emergence of a hybrid economy, part capitalist market and part sharing economy on the Collaborative Commons. To the extent that capitalism can create new business models and practices that will support the development of the sharing economy, it will prosper along with its offspring.

The triggering agent that's precipitating this great economic transformation is zero marginal cost brought on by the digitalization of communication, energy, and transport, and now the introduction of the Internet of Things platform. Businesses have always sought new technologies that could increase productivity and reduce the marginal cost of producing and distributing goods and services, in order to lower their prices, win over consumers and market share, and return profits to their investors. They never anticipated, however, a technology revolution that might unleash "extreme productivity" bringing marginal costs to near zero, making information, energy, and many physical goods and services nearly free, abundant, and no longer subject to market exchanges. That's now beginning to happen.

The near zero marginal cost phenomenon wreaked havoc across the "information goods" industries over the past decade as millions of consumers turned prosumers and began to produce and share their own music via file sharing services, their own videos on YouTube, their own knowledge on Wikipedia, their own news on social media, and even their own free e-books on the World Wide Web. The zero marginal cost phenomenon brought the music industry to its knees, shook the film industry, forced newspapers and magazines out of business, and crippled the book publishing market.

Meanwhile, six million students are currently enrolled in free Massive Open Online Courses (MOOCs) that operate at near zero marginal cost and are taught by some of the most distinguished professors in the world, and receiving college credit, forcing universities to rethink their costly business model.



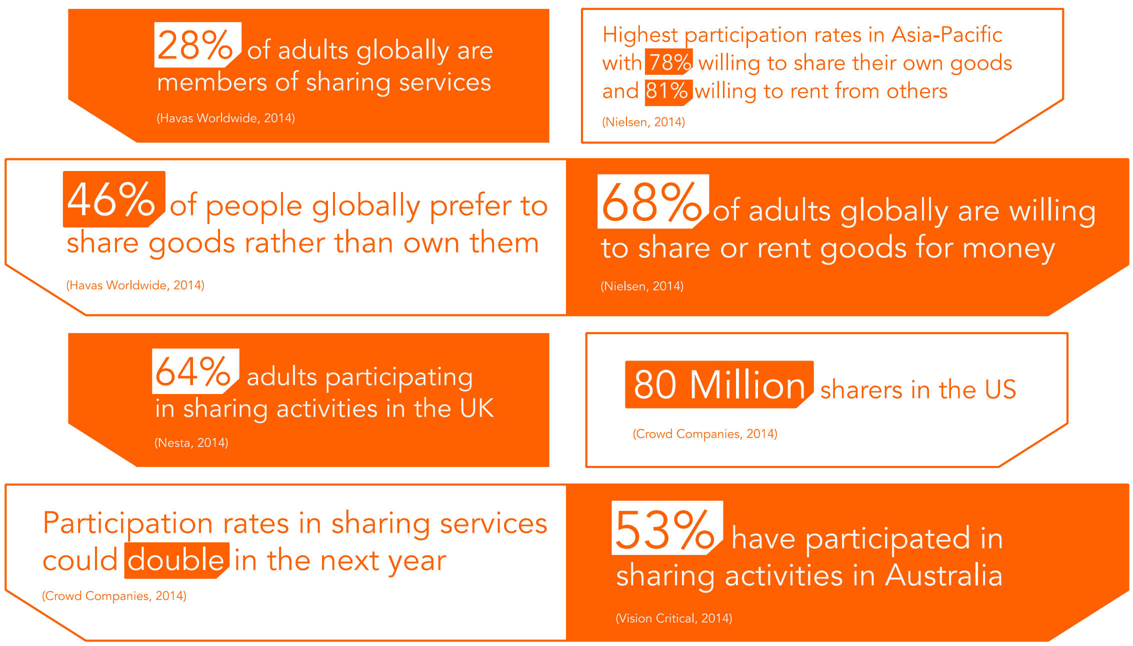
Source: Benita Matofska (2015) What we Know about the Global Sharing Economy, Compare and Share, March 2015, http://www.thepeoplewhoshare.com/reports/

While many traditional industries suffered, the zero marginal cost phenomenon also gave rise to a spate of new entrepreneurial enterprises including Google, Facebook, Twitter, and YouTube, and thousands of other Internet companies, who reaped profits by creating new applications and establishing the networks that allow the Sharing Economy to flourish.

Economists acknowledge the powerful impact zero marginal cost has had on the information goods industries, but until recently, have argued that it would not pass across the firewall of the virtual world into the brick-and-mortar economy of energy, and physical goods and services. That firewall has now been breached.

The Internet of Things platform is emerging, allowing millions—and soon hundreds of millions—of prosumers to make and share their own energy, and an increasing array of physical products and services, at near zero marginal cost.

Participation



Source: Benita Matofska (2015) What we Know about the Global Sharing Economy, Compare and Share, March 2015, http://www.thepeoplewhoshare.com/reports/

Digital interconnectivity across virtual, physical, and biological borders and across every sector of society is already challenging some of our most cherished beliefs about economic, social, and political life. In the digitalized Sharing Economy, social capital is as vital as market capital, access is as important as ownership, sustainability supersedes consumerism, collaboration is as crucial as competition, virtual integration of value chains gives way to lateral economies of scale, intellectual property makes room for open sourcing and creative commons licensing, GDP becomes less relevant, and social indicators become more valuable in measuring the quality of life of society, and an economy based on scarcity and profit vies with a zero marginal cost society where an increasing array of goods and services are produced and shared for free in an economy of abundance.

People in Luxembourg and around the world are already transferring bits and pieces of their economic life to the Sharing Economy. Prosumers are not only producing and sharing their own information, news, knowledge, entertainment, green energy, transportation, and 3D-printed products in the Sharing Economy at near zero marginal cost. Forty percent of the US population is actively engaged in sharing homes, toys, tools, and countless other items. For example, millions of apartment dwellers and home owners are sharing their living quarters with millions of travelers, at near zero marginal cost, using online services like Airbnb and Couchsurfing. In New York City alone, Airbnb's 416,000 guests who stayed in houses and apartments between 2012 and 2013 cost the New York hotel industry 1 million lost room nights.

Source: Benita Matofska (2015) What we Know about the Global Sharing Economy, Compare and Share, March 2015, http://www.thepeoplewhoshare.com/reports/

The exponential growth of the Sharing Economy raises a number of critical policy and regulatory questions that will need to be addressed by Luxembourg. New regulations will have to be enacted to ensure the social security benefits of a growing freelance workforce. Additional regulatory policies will need to be adopted to promote a level playing field between the market economy and the Sharing Economy.

Procedures will need to be put in place to track and record shared work and the exchange of goods and services for the purposes of charging taxes, measuring social security contributions, and providing accurate statistics for national accounting purposes. The Sharing Economy will also require new codes and regulations to ensure product safety and protect consumer rights.

The migration of employment from the automated market economy to the Sharing Economy and social economy is going to fundamentally change the nature of work. Government agencies, universities, and think tanks will need to explore, analyze, and assess how the changing nature of employment – flexible working hours, part time employment, and augmented virtual reality work environments – will affect quality of life indicators, including changes in conception of selfhood and identity, sociability, and cultural affiliations.

The digital Third Industrial Revolution not only impacts job opportunities and the working environment in the mid to long term, but is already changing today's working conditions. The massive diffusion of digital tools changes the way work is being organized, structured and executed. Digitalisation creates new possibilities such as remote working and virtual teams. The other side of the coin is the acceleration of work, new command and control options, and the risk of information and communication overload. In addition, digitalization brings on a spate of new issues regarding changes in management and training. To benefit both employers and employees, related work-life balance and legal issues will need to be tackled.

The advent of the Sharing Economy via online intermediation platforms also raises specific questions regarding working conditions and social welfare by service providers who share assets, resources, time and skills. Substantial new questions arise with the emergence of the Sharing Economy. For example, are services providers – car share drivers and home sharing providers – engaged by companies like Uber and Airbnb independent contractors or employees of the companies whose platforms they use? The classification depends on the degree of subordination or dependency between service provider and intermediation platform and is crucial in terms of social insurance coverage, working hours, working place safety and the like. The quality of the job (formal or informal) and the income generated are connected issues.

The emergence and maturation of the Sharing Economy alongside the conventional capitalist market will require a rethinking of regulations, codes, and standards at the state level in Luxembourg.

Quality of Life Indicators

While economic stagnation may be occurring for many other reasons, a more crucial change is just beginning to unfold which could account for part of the sluggishness: the slow demise of the capitalist system and the rise of a Collaborative Commons in which economic welfare is measured less by the accumulation of market capital and more by the aggregation of social capital. The steady decline of GDP in the coming years and decades is going to be increasingly attributable to the changeover to a vibrant new economic paradigm that measures economic value in totally new ways.

Nowhere is the change more apparent than in the growing global debate about how best to judge economic success. The conventional GDP metrics for measuring economic performance in the capitalist marketplace focus exclusively on itemizing the sum total of goods and services produced each year with no attempt to differentiate between negative and positive economic growth. An increase in expenditures for cleaning up toxic waste dumps, police protection and the expansion of prison facilities, military appropriations, and the like are all included in gross domestic product.

Today, the transformation of economic life from finance capital and the exchange of goods and services in markets to social capital and the sharing of goods and services in the Collaborative Commons is reshaping society's thinking about how to evaluate economic performance. The European Union, the United Nations, the Organization for Economic Co-operation and Development (OECD), and a number of industrialized and developing countries have introduced new metrics for determining economic progress, emphasizing "quality of life" indicators rather than merely the quantity of economic output.

Social priorities, including educational attainment of the population, availability of health-care services, infant mortality and life expectancy, the extent of environmental stewardship and sustainable development, protection of human rights, the degree of democratic participation in society, levels of volunteerism, the amount of leisure time available to the citizenry, the percentage of the population below the poverty level, and the equitable distribution of wealth, are among the many new categories used by governments to evaluate the general economic welfare of society.

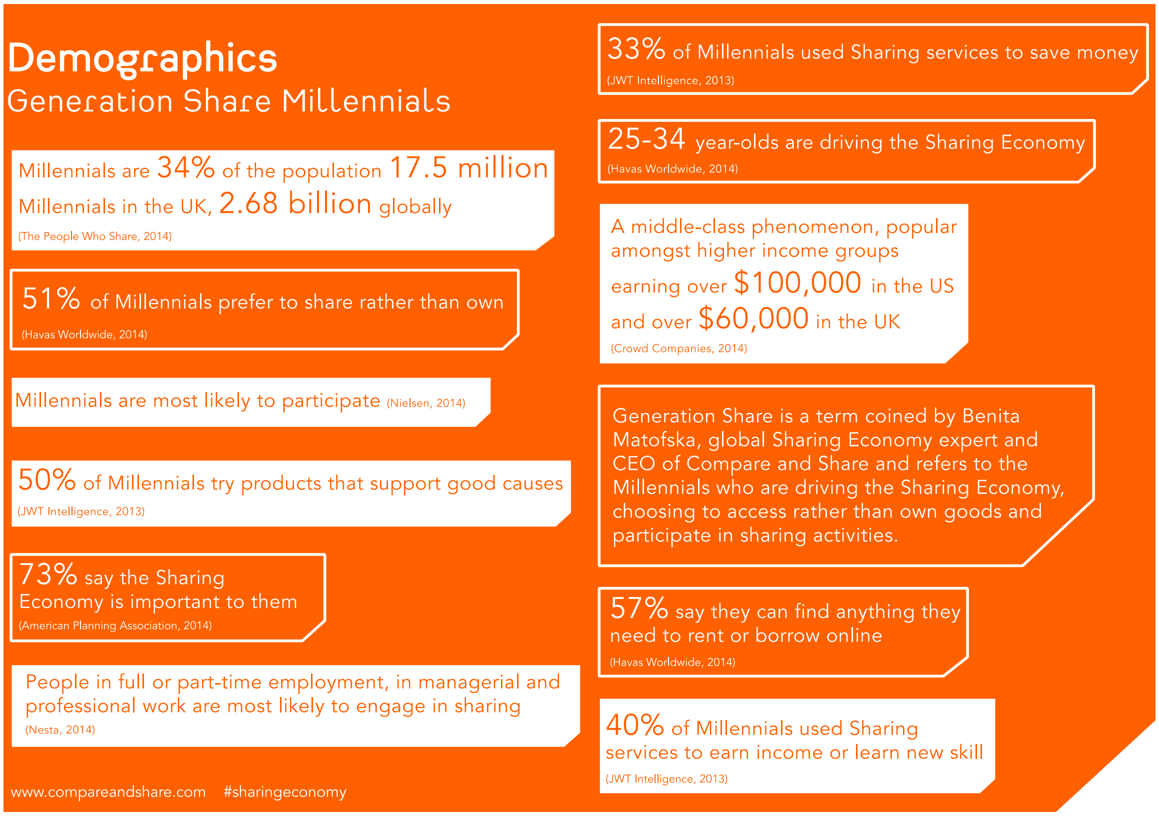
The GDP metric will likely decline in significance as an indicator of economic performance along with the diminution of the market exchange economy in the coming decades. By midcentury, quality of life indices on the Collaborative Commons are likely to be the litmus test for measuring the economic wellbeing of every nation.

In the unfolding struggle between the exchange economy and the Sharing Economy, economists' last fallback position is that if everything were nearly free, there would be no incentive to innovate and bring new goods and services to the fore because inventors and entrepreneurs would have no way to recoup their up-front costs. Yet millions of prosumers are freely collaborating in social Commons, creating new IT and software, new forms of entertainment, new learning tools, new media outlets, new green energies, new 3D-printed manufactured products, new peer-to-peer health-research initiatives, and new nonprofit social entrepreneurial business ventures, using open-source legal agreements freed up from intellectual property restraints.

The upshot is a surge in creativity that is at least equal to the great innovative thrusts experienced by the capitalist market economy in the twentieth century. The democratization of innovation and creativity on the emerging Collaborative Commons is spawning a new kind of incentive, based less on the expectation of financial reward and more on the desire to advance the social well-being of humanity. And it's succeeding.

While the capitalist market is not likely to disappear, it will no longer exclusively define the economic agenda for civilization. There will still be goods and services whose marginal costs are high enough to warrant their exchange in markets and sufficient profit to ensure a return on investment. But in a world in which more things are potentially nearly free, social capital is going to play a far more significant role than financial capital, and economic life is increasingly going to take place on a Collaborative Commons.

Recent surveys underscore the broad economic potential of the Sharing Economy. A comprehensive study found that 62 percent of Gen Xers and Millennials are attracted to the notion of sharing goods, services, and experiences in Collaborative Commons. These two generations differ significantly from the baby boomers and World War II generation in favoring access over ownership. When asked to rank the advantages of a Sharing Economy, respondents to the survey listed saving money at the top of the list, followed by impact on the environment, lifestyle flexibility, the practicality of sharing, and easy access to goods and services. As for the emotional benefits, respondents ranked generosity first, followed by a feeling of being a valued part of a community, being smart, being more responsible, and being a part of a movement.



Source: Benita Matofska (2015) What we Know about the Global Sharing Economy, Compare and Share, March 2015, http://www.thepeoplewhoshare.com/reports/

STATE OF PLAY AND LUXEMBOURG VISION

How likely is it that the Sharing Economy will play an ever-larger role in the economic life of Luxembourg in the coming decades? According to an opinion survey conducted by Latitude Research, "75% of respondents predicted their sharing of physical objects and spaces will increase in the next five years." Many industry analysts agree with these optimistic forecasts. *Time* magazine declared collaborative consumption to be one of its "10 ideas that will change the world."[336]

[336] See: http://content.time.com/time/specials/packages/article/0,28804,2059521_2059717_2059710,00.html

Interestingly enough, Luxembourgers are less engaged in the Sharing Economy than many other countries, but are likely to increase their participation in the years ahead. According to a 2015 survey of Luxembourgers by ING Luxembourg, 24% of Luxembourg residents know about the sharing economy, 33% would consider sharing their household appliances for money, 8.9% would be willing to share their holiday home, and 20% believe their participation in the sharing economy will increase.[337]

The Social Dimension

The shift to a prosumer Sharing Economy is as much about the values a society shares as it is about the technologies it introduces. The future configuration of Luxembourg society and economic life is not fated, but the result of today's choices and decisions. Technological changes are not an end in themselves, but tools to ameliorate our society. Public authorities, businesses, social partners, civil society and citizen movements must work together to jointly shape the transformation of society. The human dimension must be considered to ensure the acceptance of the TIR process. The transition to a Third Industrial Revolution will not be achieved by technological development and innovation alone. Societal issues must be considered as well. Technological changes are inextricably linked to changes in mindset. A broad approach allows taking all actors towards TIR and helps explain both the opportunities and concerns related to upcoming changes. In summary, the empowerment of the consumer and societal aspects set the frame for the working group "Prosumers & Social Model."

Living together is based on ethical and moral values which are essential and vital elements of our society. For instance, human rights are an integral part of these values, and compliance with them should never be taken for granted, but rather be seen as a process to be continually monitored. It is, therefore, necessary to assure that the respect of common values frames the transition to the TIR. In a recent nation branding process, conducted by an inter-ministerial and inter-institutional coordination committee and involving a wide variety of Luxembourg society as well as the general public, participants crowd sourced a profile of Luxembourg's citizenry. Reliability, dynamism, and openness were identified as the country's most distinguishing characteristics and core strengths. Reliability refers to the solid foundations on which Luxembourg performs its activities and to the stability of its economy. Dynamism reflects Luxembourg's ability to reinvent itself and adapt to changing surrounding conditions. The way in which Luxembourgers make decisions and take action is characterized by pragmatism and a commitment to constant improvement. The country's openness is a key component of its

[337] See: https://www.ing.lu/web/ING/NL/Particuliers/News/NEWS_20150723_SHARECO_NL

economic development and model of society.

As the cosmopolitan crossroad in the heart of Europe and a driving force for the Greater Region, Luxembourg experiences cross-border cooperation on a daily basis. Luxembourg, where economic actors can benefit from an enormous concentration of international expertise, displays open-mindedness to new and innovative ideas.

Given these characteristics, the archetype of “the ally” best reflects the country’s identity: that is, working together to generate common growth by virtue of solid partnerships and a commitment to the common good. The ally achieves his objectives thanks to his particular ease in creating cooperation, alliances and communities. Luxembourg’s qualities, described above, perfectly match the digitalized Sharing Economy on the Collaborative Commons where social capital, lateral power and collaboration are decisive. Brought on by the Third Industrial Revolution, amplified by the emerging Internet of Things platform and triggered by zero marginal cost, the Sharing Economy is expected to grow and become a complementary economic model.

Besides the emergence of the Sharing Economy, the economic transformation spawned by TIR goes along with socio-cultural mutations. One essential requirement for societal change is literacy in the broadest sense. People need to understand the impacts of their actions. Raising awareness and, in particular, biosphere consciousness is necessary to make sure that future development targets economic, societal and environmental resilience. Development is rarely straight forward but, rather, characterized by disruptions and evolution by leaps and bounds.

The participants of the working group pointed to different roles and missions of the state and public authorities. First of all, the group made a distinction between specific missions in the context of the TIR, notably to enable and facilitate economic and social development, and the more general missions of guaranteeing social protection and cohesion, environmental conservation and a stable quality of life.

One key mission of the State relative to the Third Industrial Revolution is to provide the necessary infrastructure to allow economic activity to flourish. The requirements include material infrastructure such as roads, high-performance telecommunication equipment, adapted energy transportation and distribution grids etc., as well as an immaterial framework which includes legislation, regulation and policies. Luxembourg set the course for the transition into the TIR with the government’s economic diversification policy, where ICT and logistics upgrades of the energy infrastructure were earmarked as critical priorities.

Public health is another sector where Luxembourg has leaped foreward by digitalizing its health records. The recently created national agency on shared information in the domain of health

(Agence eSanté) provides individual electronic health record (Dossier de Soins Partagé) to ease the exchange of information between health professionals and provide a more coordinated and efficient form of assistance for the patient. The health and care sectors offer various opportunities for TIR applications – for example, the self-tracking of body parameters to quantify biometrics including heart rhythm, insulin, and cortisol levels. The technology can be used for remote monitoring and medical assistance. ICT and Internet of Networks technology also allow health professionals to track the spread of epidemics and to inform the population in situations where public health is at risk.

The State also needs to guarantee social protection and cohesion, environmental conservation and a stable quality of life by meeting the needs for autonomy, good health, adequate housing, healthy alimentation, mobility, sufficient rest, and so on. Public authorities need to defend the common welfare and the best interests of citizens, including the protection of the weak and vulnerable populations. In general, governmental action should therefore be aimed at preventing an increase of inequalities and a marginalization of parts of the population in the digital era, as this is essential to social cohesion. Also, it is particularly important to leave no one behind in the TIR process. Considering Luxembourg's heterogenic resident and working population, this is an outstanding challenge for the country.

To support the transition towards a more sustainable socio-economic model, public authorities should encourage enlightened and interested citizens who are conscious of their responsibilities, rights and obligations. In addition, public authorities should express their commitment to sustainable development by exemplary actions like including social and environmental criteria in public procurement.

Digitalization, in general, and the Communication Internet, in particular, changes the profile and the role of the consumer. The Communication Internet not only offers easier access to information about commercial offers and product characteristics, but also gives the consumer new possibilities to get involved in the economic process. Just as digitalization and the Communication Internet allows people to produce and share virtual goods such as music, videos, books or knowledge, the emerging Internet of Things platform may extend the prosumer and the Sharing Economy concept to more and more sectors of the brick-and-mortar economy of energy and physical goods.

As consumers become producers as well, they are confronted with new obligations to be respected and satisfied. This concerns questions about product safety and consumer rights, as well as commercial and fiscal issues. Here, one major point is to sensitize and inform the (nonprofessional) prosumers about their legal duties and obligations when acting as producer or service provider.

The increasing emergence of prosumers is strongly linked to the spread of sharing and a collaborative economy, characterized by a flat hierarchy, lateral power and network organization. The Sharing Economy covers a multitude of different business models, all of which aim to optimize resource use in order to lower utilization costs or reduce environmental impacts. To evaluate, in the best possible way, the impact the Sharing Economy is having on the society and the environment, it is essential to know the different specifications and characteristics of this new economic paradigm as well as the people's motivation to participate in sharing activities. These activities can be classified into three different types of Sharing Economy operating models: 1) peer-to-peer exchanges using internet sites as intermediation platforms; 2) object sharing implying a (public or private) third party owning the goods to be shared; 3) collaborative models where users manage the resources and means of production themselves. The impact of digitalization and the use of the Internet of Things infrastructure vary considerably, depending on the respective activity and operating model.

Peer-to-peer exchanges, mostly between private persons, include buying, selling, lending and sharing of new and used goods, as well as services. Whereas the trade of second-hand goods – via eBay or similar online intermediation platforms – presents limited competition to commerce, the impact is different for selling new goods or providing services via internet platforms. If such businesses are operated by private persons, i.e. via Uber for mobility purposes or Airbnb for accommodation issues, these enter into direct competition with conventional commerce and require that the state guarantee a level playing field between the emerging Sharing Economy and existing market economy businesses. The State must ensure, via legal action, that different business models conform to the same regulations and that different operators and service providers comply with the same legal obligations. In the Sharing Economy however, a distinction should be made between professional actors and private persons operating only occasionally. Corresponding criteria should be fixed by regulation; in doing so, one approach could be to differentiate using thresholds, taking into account the level of income generated or the regularity with which the service is provided. It is important to make sure that all actors comply with their legal, tax and social obligations. A corresponding framework should be clarified or specified if necessary. The above distinction also matters in consumer rights, as warranties, product quality, imposed security and sanitary norms or qualifications can differ, depending on the status of the provider. Relevant information to the consumers should be clear and freely accessible. It is a big challenge to anticipate and recommend suitable regulations that remain pertinent in a rapidly and continuously changing environment. The Communication Internet acts as a stimulant and promoter for new peer-to-peer exchange models, and the deployment of an Internet of Things platform will enlarge such Sharing Economy models to more economic sectors.

Object sharing implying a (public or private) third party owning the goods to be shared is currently most common in the mobility sector. Offers like Vel'Oh and Carloh (Luxembourg-City), Vël'ok (initiated by CIGL Esch/Alzette and supported by eight municipalities in the south of Luxembourg) or Nordstad-eMovin (in the north of Luxembourg) are mobility services that place bikes or cars at the disposal of the public. Such initiatives favor access to mobility over bike or car ownership. Internet of Things technology benefits the spread of such initiatives. Sensors allow tracking the vehicles and evaluating and controlling their use. Employing mobile apps, users can be informed about the availability of a vehicle, perform reservations or pay the utilization fees. A 2016 analysis by Morgan Stanley estimates the global market for shared mobility services by 2030 will exceed *$2.5 trillion* per year.[338] The estimate is based on shared mobility comprising one-fourth (26%) of 20 trillion miles driven worldwide at a cost of 28 euro cents per kilometer.[339]

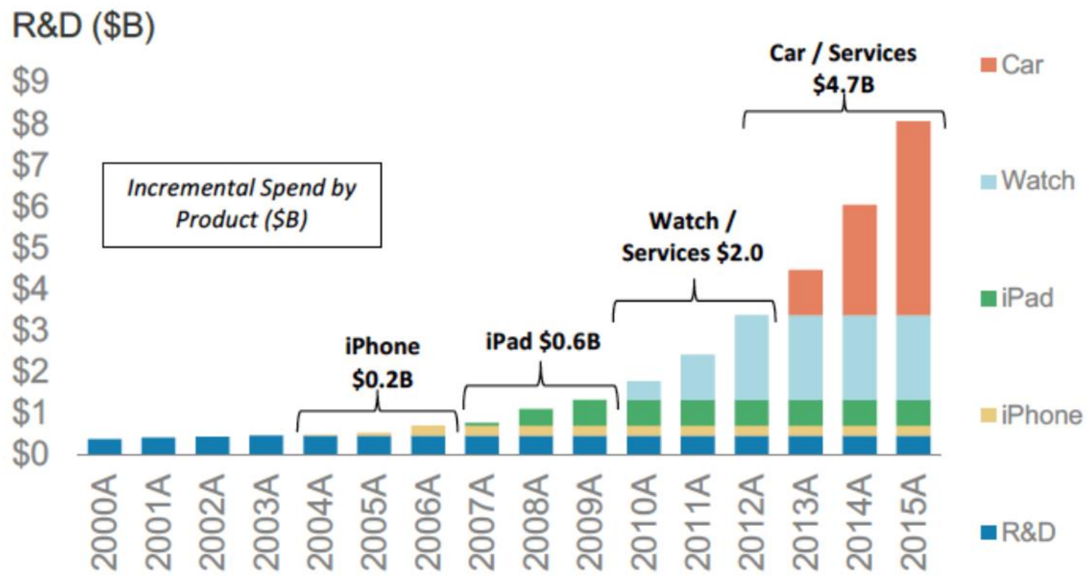
A third type of sharing is the collaborative model where users themselves manage the resources and means of production. Community supported agriculture and energy cooperatives are current examples of this type of activity, but so too are the common creation and sharing of immaterial goods such as knowledge pools (i.e. Wikipedia), open source software, and open design, etc., or commodities (open hardware) produced via community owned 3D printers. Unlike the two other operating models described above, collaborative models require a high level of confidence between the users and confidence in the community as a whole. Social capital is vital. While the use of Internet of Things technology for all of these initiatives is not essential, it can help boost productivity and reduce marginal costs for these activities.

Morgan Stanley's bullish future for shared mobility is based on the current trend of Internet companies' investments – Apple, Google, Alibaba, etc. – in the mobility sector. Apple, for example, now spends more on mobility R&D than is collectively spent by the top 14 auto manufacturers; or $5 billion compared to $192 million, respectively.[340]

[338] Hanley, Steve (2016) Shared Mobility Will Be $2 Trillion Market By 2030, *Gas2.com*, June 5, 2016, http://gas2.org/2016/06/05/shared-mobility-will-2-trillion-market-2030/.

[339] Elmer-DeWitt, Philip (2016) Morgan Stanley is bullish on the Apple car, *Ped.com*, May 25, 2016, http://ped30.com/2016/05/25/apple-car-morgan-stanley/

[340] Ray, Tiernan (2016) Apple R&D Way More Than Detroit, Says Morgan Stanley; Big Cloud Spending? *Barron's*, May 25, 2016, http://blogs.barrons.com/techtraderdaily/2016/05/25/apple-rd-way-more-than-detroit-says-morgan-stanley-big-cloud-spending/.



Source: Morgan Stanley Research, cited in Elmer-DeWitt (2016)

Internet companies have established a number of partnerships with auto makers. Apple recently made a $1 billion investment in Didi Chuxing, Uber's rival ride-sharing service in China.[341] Morgan Stanley projects China's ride-sharing market to be worth $145 billion by 2020 and $500 billion by 2030. Google is partnering with Chrysler on autonomous driven mini-vans while General Motors has invested half a billion dollars in the ride-sharing business Lyft and has bought ride-sharing start-up Cruise Automation for a billion dollars.[342] IBM has teamed with start-up 3D auto printing company, Local Motors, in designing and producing the 3D printed self-driving electric shuttle van, "Ollie",[343] while Volkswagen's 2025 Strategy announced in May 2016, is essentially an Internet of Mobility product-as-a-service proclamation.[344]

To the knowledge of the working group, no comprehensive general survey on the Sharing Economy exists for Luxembourg. In order to address this, the working group suggests a

[341] Bennett, Johanna (2016) Morgan Stanley: More to Apple's Didi Chuxing Investment "Than Meets the Eye", Barron's, May 16, 2016, http://blogs.barrons.com/techtraderdaily/2016/05/16/morgan-stanley-more-to-apples-didi-chuxing-investment-than-meets-the-eye/.

[342] *Op cit*., Hanley (2016).

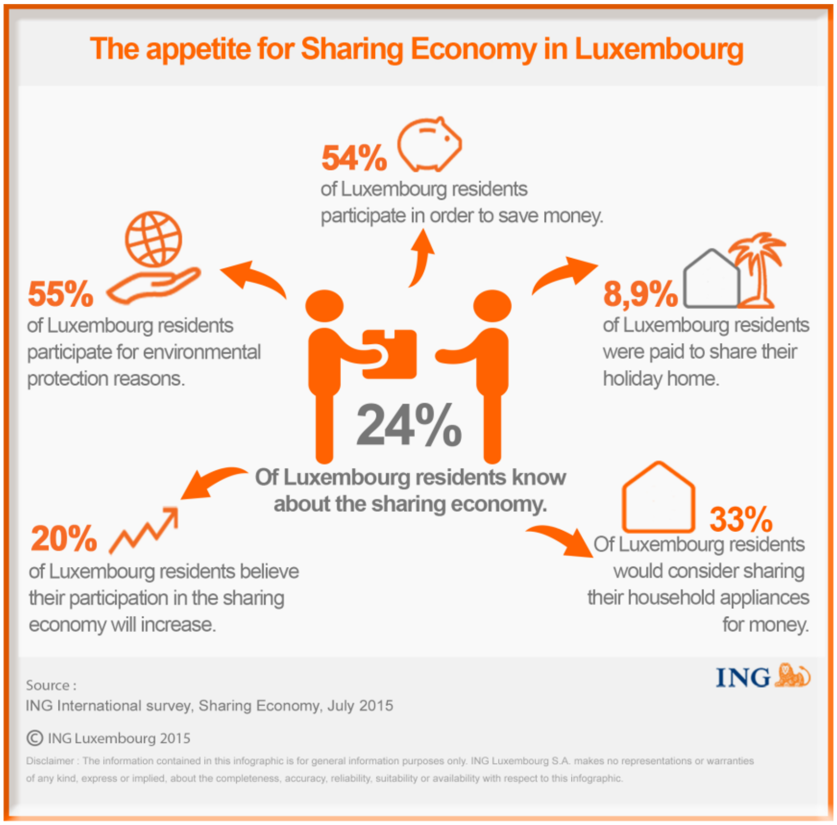
[343] Mlot, Stephanie (2016) IBM Watson Powers 'Olli' Self-Driving Van, PC Magazine, June 16, 2016, http://www.pcmag.com/news/345338/ibm-watson-powers-olli-self-driving-van.

[344] Schmitt, Bertel (2016) Volkswagen Strategy 2025: Connectivity, Electrification And Strange Dreams Of An Apple Takeover, *Forbes*, May 24, 2016, http://www.forbes.com/sites/bertelschmitt/2016/05/24/volkswagen-strategy-2025-and-the-secret-master-plan-for-an-apple-takeover/#5ae9af2221c5.

correspondent study. Poll results could be helpful to implement pertinent policies. Official figures and statistics about the public's acceptance of the Sharing Economy in Luxembourg are missing. One reason is the methodological difficulty in tracking and measuring peer-to-peer sharing activities, especially those relying on non-monetary exchanges. Further analysis is required in this domain to enable the integration of value added generated by activities based on new economic models into national accounts by the national statistical office (STATEC) and to consider these activities in the calculation of the economic performance of Luxembourg. Although peer-to-peer exchanges are not a new phenomenon, digitalization of the economy increases the scale of these transactions and makes related measurement issues an urgent priority. Underlying activities have been traditionally captured in national statistics using numerous approaches related to the informal and non-observed economy. The use of intermediation websites may provide a solution to measure generated value in a more accurate way. To this effect, Luxembourg could explore the feasibility of using data collected by intermediary service providers to improve the estimates of activities of unincorporated enterprises. The topic also contains a fiscal issue as precise tracking and measuring is a prerequisite for subjecting these activities to the tax code and allowing the state to collect taxes.

Concerning the measurement of GDP, another issue must be broached: free assets produced by users. While using (free) digital products, vast amounts of data are generated. This data represents a value asset for the provider as it is collected and commercially exploited (data mining, Big Data analytics, sale to data brokers, etc.). The value added by the users is difficult to evaluate. When the provider is registered in the same country as the user, there should be no impact on total GDP as the whole value is generated in the same national territory and the provider's activity is likely to be captured in national accounts. However, when provider and user are not registered in the same country, there may be an impact on GDP as part of the value chain – namely the value generated by the user is not accounted for in the country it was generated. A related topic is the creation of public goods using labor provided for free. Typical examples in this domain are open source software (e.g. Linux) and knowledge (e.g. Wikipedia). Within the current accounting framework, the services provided by prosumers and the time they spend on developing or improving the public good do not enter into GDP.

The creation – within a public administration – of a directorate in charge of the Sharing Economy and all related issues could help to bundle the efforts and deal with the different aspects of the Sharing Economy in a target-oriented way.



Source: ING Luxembourg (2015)

Employment

The values and operational principles of the Sharing Economy place it in a realm between the capitalist market and the nonprofit sector. As mentioned in the Industry Working Group report, in the short to mid-term – forty years – tens of thousands of semi-skilled, skilled, and professional workers will be required to build out and scale up the smart Internet of Things infrastructure of the Third Industrial Revolution in Luxembourg. This will require a significant retraining in the skillsets necessary to introduce a smart digital technological platform and accompanying business models. In the long run, the phase-in of a smart Digital Luxembourg will ultimately lead to a highly automated capitalist market economy, operated by small professional and supervisory workforces using advanced analytics, algorithms, and artificial intelligence. The maturing of this smart infrastructure will lead to a migration of employment from an increasingly automated capitalist market to the growing social economy. While fewer human beings will be required to produce goods and services in the market economy, machine surrogates will play a smaller role in the nonprofit social economy for the evident reason that deep social engagement and the amassing of social capital is an inherently human enterprise. The social economy is a vast realm that includes education, charities, healthcare, child and senior care, stewardship of the environment, cultural activity and the arts, sports and entertainment, all of which require human-to-human engagement.

In dollar terms, the world of nonprofits is a powerful force. Nonprofit revenues grew at a robust rate of 41 percent—after adjusting for inflation—from 2000 to 2010, more than doubling the growth of gross domestic product, which increased by 16.4 percent during the same period. In 2012, the nonprofit sector in the United States accounted for 5.5 percent of G.D.P.

The nonprofit sphere is already the fastest-growing employment sector in many of the advanced industrial economies of the world. Aside from the millions of volunteers who freely give of their time, millions of others are actively employed. In the 42 countries surveyed by the Johns Hopkins University Center for Civil Society Studies, 56 million full-time workers are currently employed in the nonprofit sector.

In some countries, employment in the nonprofit arena makes up more than 10 percent of the workforce. In the Netherlands, nonprofits account for 15.9 percent of paid employment. In Belgium, 13.1 percent of the workforce is in the nonprofit sector. In the United Kingdom, nonprofit employment represents 11 percent of the workforce, while in Ireland it's 10.9 percent. In the United States, nonprofit employment accounts for 9.2 percent of the workforce, and in Canada it's 12.3 percent.

These percentages will likely rise steadily in the coming decades as employment switches from a highly automated market economy to a highly labor-intensive social economy. Students will need to be educated for the new professional skills that come with the job opportunities opening up in the social economy. Although a massive effort will be required, the human race has shown itself capable of similar efforts in the past—particularly in the rapid shift from an agricultural to an industrial way of life between 1890 and 1940.

Despite the dramatic growth curve in employment in the social economy, many economists look at it askance, with the rejoinder that the nonprofit sector is not an independent economic force but rather largely dependent on government-procurement contracts and private philanthropy. One could say the same about the enormous government procurements, subsidies, and incentives meted out to the private sector. But this aside, the Johns Hopkins study of 42 countries revealed that contrary to the view of many economists, approximately 50 percent of the aggregate revenue of the nonprofit sector already comes from fees for services, while government support accounts for only 36 percent of the revenues, and private philanthropy for only 14 percent.

By mid-Century, if not sooner, a sizeable percentage of people employed around the world will be in the nonprofit sector, busily engaged in advancing the social economy, and purchasing at least some of their goods and services in a highly automated capitalist marketplace.

John Maynard Keynes's futurist essay, written more than 80 years ago for his grandchildren, envisioned a world where machines have freed up human beings from toil in the marketplace to engage in deep cultural participation in the social economy in the pursuit of more lofty and transcendent goals. It might prove to be his most accurate economic forecast.

Preparing students for the opportunities and challenges that accompany the transition into a Digital Luxembourg and a Third Industrial Revolution economy requires a fundamental rethinking of the nature of education. According to the Pearson survey on Education and Skills for Life, which ranks the top performing public school systems in the world, Luxembourg is not included among the top 40 educational systems, suggesting that Luxembourg will have to undergo a steep transformation in its educational practices.

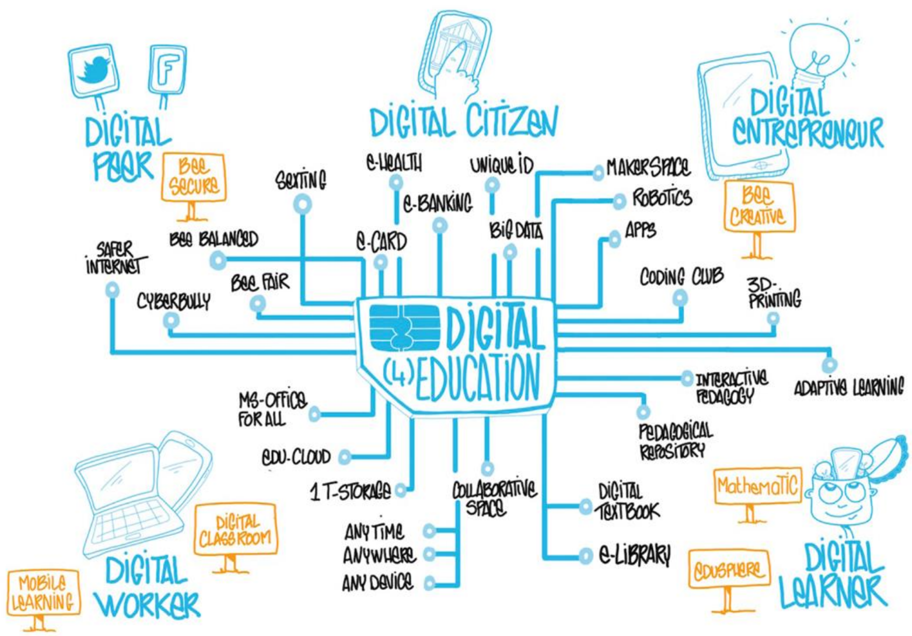
Education, Elucidation and Information

The Working Group makes compelling arguments about the need for transforming the educational experience so that youngsters obtain early experience on what it means to be enterprising and "digitally savvy." Transversal skills such as critical thinking and reflection, systems thinking, networking, empowering and participation are future key factors for bringing about positive economic and social change. In relation to TIR, two topics must be addressed: 1) the identification and education of future-proof skills to meet labor market needs and 2) the use of new technologies for knowledge transfer.

To fit the requirements of 21st Century, students should learn in a social and participatory way. Input from the business community and civil society should be included in school curricula. Interdisciplinary projects linking theory and practice could enrich education and widen student's horizon. A crucial aspect to ensure a high quality of education is the training of teaching staff. Teachers need a high level of digital literacy to impart digital knowledge and skills.

This is well recognized by the Ministry of National Education, Children and Youth, in its efforts to prepare schools and students to the challenges of the 21st Century. The aim of Luxembourg's schools is to form young people able to adapt to a fast changing environment. Therefore, learning situations favoring comprehension of society and the world, individual fulfilment, and personal well-being must be created. Skills must be developed in four essential domains: communication, collaboration, creativity and critical thinking.

Digital(4)Education is a new Luxembourg government ICT initiative launched in 2015. "The main objectives of the strategy are firstly a digital education, meaning to prepare students for a complex and continuously changing work environment as well as for their role as citizen, and secondly the promotion of new learning strategies and innovative pedagogic projects using digital technologies. The strategy is built on the following five dimensions: 1) ***digital citizen***, initiating students in essential ICT-based applications like administrative procedures, communication with authorities, e-banking, etc. 2) ***digital peer***, broaching issues on the safe and responsible use of the internet, 3) ***digital learner***, creating the required learning environment, 4) ***digital worker***, teaching basic technological tools and 5) ***digital entrepreneur***, offering activities to stimulate talents and encourage the students to deal with ICT tools." (See visual below)



Source: Digital4education, http://portal.education.lu/digital4education/

With the ubiquitous access to inexpensive smart phones, a profound transformation has been unleashed. Each individual with access to a smartphone or tablet (hand-held device) essentially has a pocket supercomputer. This situation increases the degrees of freedom for an individual in having access to an essentially limitless amount of information and knowledge, but also imposes new social responsibilities and obligations. The responsibilities turn on taking initiatives in pursuing one's educational needs and recognizing that literally in their hands is the largest open source library in the history of humankind for pursuing life-long learning.

As such, the incumbent role of government is to instill in each citizen the responsibility to take advantage of these digital resources, tools, and networking opportunities to pursue self-motivated and directed learning that is essential for future proofing themselves in a world fraught with sudden changes, constant uncertainties and unexpected surprises. Becoming digitally savvy means taking the responsibility to enhance one's personal human capital, while engaging and networking with peers (both locally and globally) to cultivate social, civic, and intellectual capital. By cultivating these new opportunities daily, each individual ensures skills and competences are being cultivated for future proofing their odds of worth and insuring against becoming a stranded asset.

The First and Second Industrial Revolutions enshrined a model of teaching designed to prepare students to be skilled industrial workers. The classroom was transformed into a microcosm of the factory. Students were thought of as analogous to machines. They were conditioned to follow commands, learn by repetition, and perform efficiently. The teacher was akin to a factory foreman, handing out standardized assignments that required set answers in a given time frame. Learning was compartmentalized into isolated silos. Education was supposed to be useful and pragmatic. The "why" of things was less discussed than the "how" of things. The goal was to turn out productive employees.

The Third Industrial Revolution is altering the pedagogy of the classroom. The authoritarian, top-down model of instruction is beginning to give way to a more collaborative learning experience. Teachers are shifting from lecturers to facilitators. Imparting knowledge is becoming less important than creating critical-learning skills. Students are encouraged to think more holistically. A premium is placed on inquiry over memorization.

In the traditional industrial classroom, questioning the authority of the teacher is strictly forbidden and sharing information and ideas among students is labeled cheating. Children quickly learn that knowledge is power, and a valuable resource one acquires to secure an advantage over others upon graduation in a fiercely competitive marketplace.

In the Digital Age, by contrast, students will come to think of knowledge as a shared experience among a community of peers. Students learn together as a cohort in a shared knowledge community. The teacher acts as a guide, setting up inquiries and allowing students to work in small-group environments. The goal is to stimulate collaborative creativity, the kind young people experience when engaged in many of the social spaces of the Internet. The shift from hierarchical power, lodged in the hands of the teacher, to lateral power, established across a learning community, is tantamount to a revolution in pedagogy.

While the conventional classroom treated knowledge as objective, isolated facts, in the collaborative classroom, knowledge is equally regarded as the collective meanings we attach to our experiences. Students are encouraged to tear down the walls that separate academic disciplines and to think in a more integrated fashion. Interdisciplinary and multicultural studies prepare students to become comfortable entertaining different perspectives and more adept at searching out synergies between phenomena.

The idea of learning as an autonomous private experience and the notion of knowledge as an acquisition to be treated as a form of exclusive property made sense in the First and Second Industrial Revolution environment. In the Collaborative Age, learning is regarded as a crowdsourcing process and knowledge is often treated as a publically shared good, available to all, mirroring the emerging definition of human behavior as deeply social and interactive in nature. The shift from a more authoritarian style of learning to a more lateral learning environment better prepares today's students to work, live, and flourish in tomorrow's collaborative economy in Luxembourg.

The new collaborative pedagogy is being applied and practiced in schools and communities around the world. The educational models in the emerging digital era are designed to free students from the private space of the traditional enclosed classroom and allow them to learn in multiple open Commons, in virtual space, the public square, and in the biosphere.

Rethinking primary, secondary, and university education in Luxembourg to prepare current and future generations for employment in both the automated capitalist marketplace and the emerging Sharing Economy will be an urgent and major priority. The Luxembourg educational system will want to explore a range of best practices emerging in school systems around the world, including extending the learning environment into the community with service learning and clinical engagement, virtual learning via Skype and FaceTime in shared global classrooms, and online learning with Massive Open Online Courses (MOOCs).

The Working Group provides a detailed summation of the myriad of challenging issues pertinent to the emergent prosumers social modes and the Sharing Economy. The WG outlines the social, ethical, legal, political, educational and financial questions being raised by business, government, academia, and consumer organizations. Even a cursory glance at the research literature already finds a prodigious number of recent publications discussing and analyzing these manifold issues. The palpable sense of urgency in raising these concerns and elevating them to the front and center attention of lawmakers goes to the heart of the industry disruption witnessed over the course of the past half-decade.

The digitization and Internetization (or IoT) driving forward the TIR is going to eventually impact every part and process of the 70 trillion euro annual global economy. While economists sanguinely forecast 2 to 3 percent average annual growth rates this century, implying a nearly 10 to 20 fold larger global economy, it is highly questionable whether economic growth based on the second industrial revolution industries and institutions can be sustained without the aggregate efficiency productivity gains catalyzed by IoT tools and technologies – especially given the massive threats of profound economic losses and social dislocation projected to occur with the continued rise in greenhouse gas emissions and decline of the biosphere's irreplaceable natural capital.

The two significant findings of "business-as-usual" trends; first, the level of unpriced economic losses now being incurred worldwide, and second, the projected economic losses from a several degree Celsius rise in global average temperature in the coming decades. The negative externalities impacting the biosphere by damaging, degrading, and destroying natural capital and ecosystem services has been calculated at $7.3 *trillion* per year (US$2009), or 13% of world GDP.[345] The future cost from a several degree C rise has been estimated at $1,240 *trillion* in net present value (US$2000).[346]

The first figure does not include disasters that may occur in business supply chains, and the latter figure does not include the catastrophic consequences from any of a dozen tipping points releasing vast levels of GHG emissions (shown in map below). With these advancing and looming catastrophes being driven, in essence, by the Second Industrial Revolution economy, the tremendous value associated with the accelerating and scaling of IoT-based tools and technologies of the TIR become imperative.

The growth of the prosumer and sharing economy made possible at large scale by IoT tools and technologies is clearly an integral component of the TIR. In the foreseeable future, it will comprise an important, but still relatively modest percentage of the larger IoT-driven growth projected to occur. This is partly explained by the exponential growth curve of IoT infusion into and throughout the economy, which belies the real progress of the prosumer/sharing economy.

PWC's 2015 report, *The Sharing Economy*, in examining five areas - tourism, vehicle sharing, finance, personnel, and streaming music & video - projects worldwide growth in sharing to one-third of a trillion dollars per year within the decade.[347] Given the veritable speciation explosion in Sharing Economy concepts and practices, the next decade will likely experience a

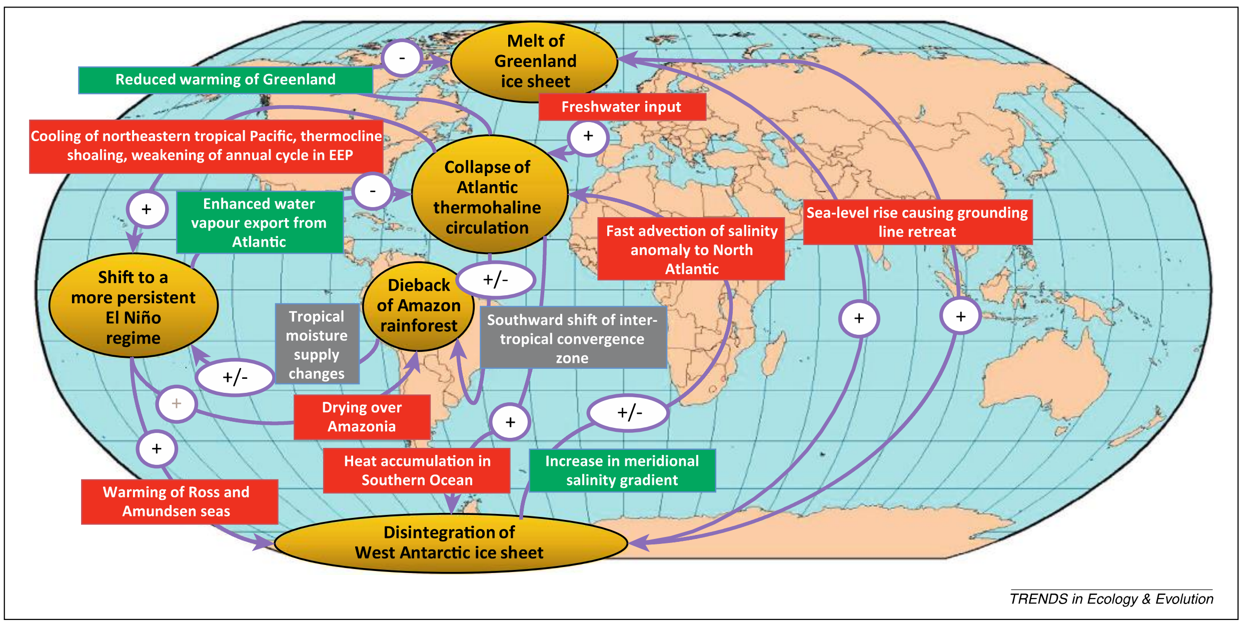
[345] TRUCOST PLC (2013) Natural Capital at Risk: The Top 100 Externalities of Business, prepared for The Economics of Ecosystems and Biodiversity (TEEB) Business Coalition.

[346] US1240 trillion is the mean estimate, with no adaptation. Martin Parry, Nigel Arnell, Pam Berry, David Dodman, Samuel Fankhauser, Chris Hope, Sari Kovats, Robert Nicholls, David Satterthwaite, Richard Ti n, Tim Wheeler (2009) *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates*, International Institute for Environment and Development and Grantham Institute for Climate Change, London.

[347] PWC (2015) *The Sharing Economy*, https://www.pwc.com/us/en/industry/entertainment-media/publications/consumer-intelligence-series/sharing-economy.html.

proliferation of entrepreneurial drives to establish large-scale changes in the way products and services are created, shipped, delivered, used, and re-circularized.

The global reality of the Sharing Economy is reflected in the diverse growth figures visually captured in the series of slides above, by Benita Matofska, CEO of The People who Share, and originator of Global Sharing Day. “Smart UK consumers who currently share are benefiting from £4.6 billion worth of savings or earnings,” Matofska has said, and “[t]he sharing economy is the people’s sustainable economy and is a good deal for everyone."[348]



Causal connections between tipping events in the climate system, as identified by participants in an expert elicitation.[349]

[348] Jennifer Elks (2013) New Research Finds UK Consumers Earning and Saving £4.6 Billion Through the Sharing Economy, *SustainableBrands.com*, May 22, 2013, http://www.sustainablebrands.com/news_and_views/social_enterprise/new-research-finds-uk-consumers-earning-and-saving-46-billion-throu?utm_source=Twitter&utm_medium=schtweets&utm_campaign=editorial

[349] Lenton, Timothy M. and Hywel T.P. Williams (2012) On the origin of planetary-scale tipping points, Trends in Ecology & Evolution July 2013, Vol. 28, No. 7. Map color explanations: “Causal connections between tipping events in the climate system, as identified by participants in an expert elicitation. Tipping events (in yellow) are connected A□B if at least five experts judged that event A had a direct effect on the probability of event B thereafter; the sign indicates increasing (+) or decreasing (–) effects, or effects of uncertain direction (+/–). A predominance of positive causal connections could give rise to a ‘tipping cascade’, but this also depends on the strength of the positive and negative connections. Here, there are more positive (red) than negative (green) and

While many or most of the sharing activities are sustainable, some lag behind in this regard. This is perhaps the crux of concerns around prosumer and sharing economy activities: are they as or more sustainable in all the ways we expect of the economic activities they are displacing, as well as fulfilling all of the legal requirements also required of the replaced economic activities (e.g., safety, insured, taxes).

Given the complexity, it is often difficult to sort out the very different kinds of economic activities emerging in the collaborative/sharing/prosumer sphere. Industry trend analyst Jeremiah Owyang has been categorizing and describing these rapidly expanding domains in updated versions of what he calls the Collaborative Economy Honeycomb. Version 3 released in 2016 is shown on the next page. The number of categories has nearly tripled since the release of the first version four years ago.

An indicator of how different these categories are is the increasing number of words and phrases being used to describe the diverse activities once captured under umbrella terms like collaborative or Sharing Economy. Ride sharing services like Uber, for example, are more accurately referred to as rental services, as are room-booking services offered by Airbnb and similar "rental economy" businesses.[350] Likewise, the "gig economy" is now used to describe the labor and wage arrangements for jobs in this "on-demand economy".[351]

Sharing Economy experts like Neal Gorenflo, co-founder of Shareable.net, provide a more blunt contrast between local wealth creating and circulating cooperative models versus the Uber-style wealth-extracting business models.

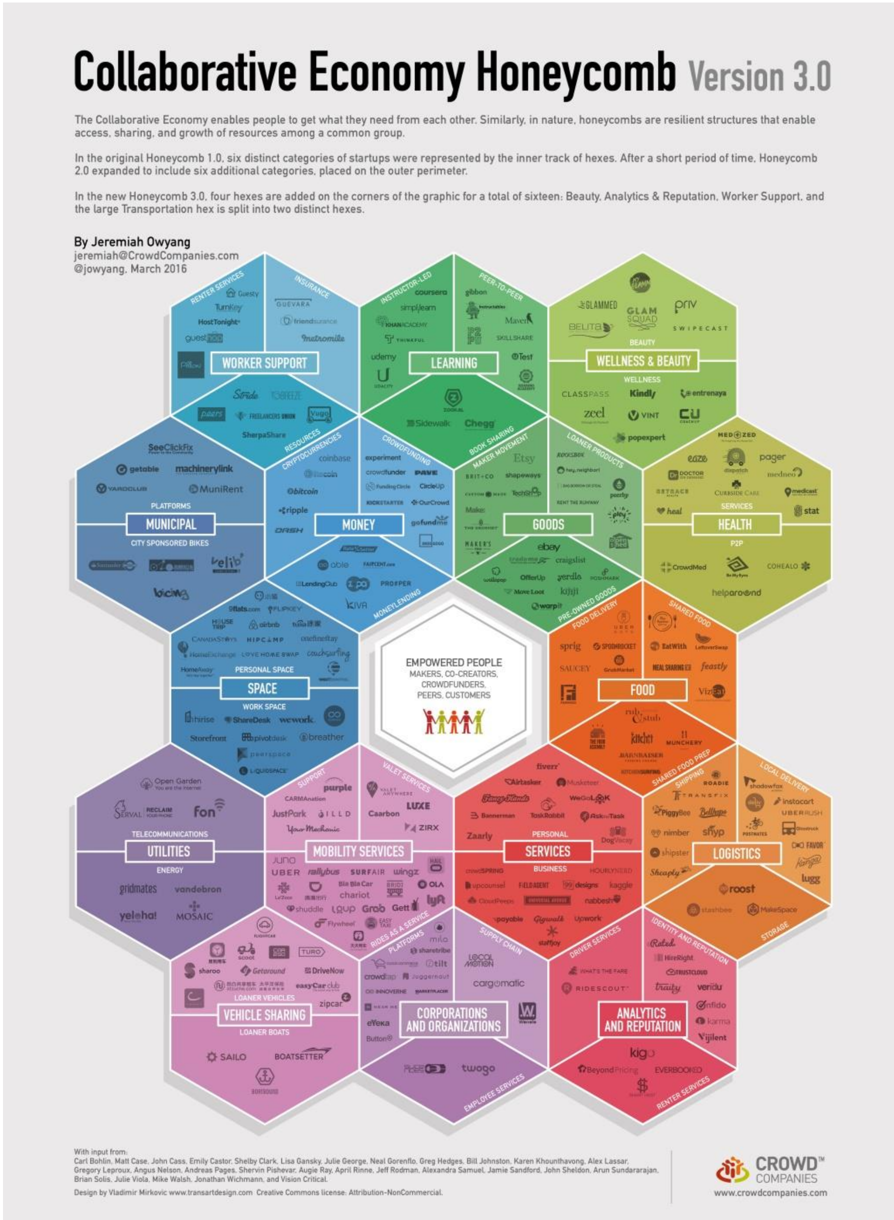
"We have an epic choice before us between platform coops and Death Star platforms, and the time to decide is now," he argues, pointing to Uber's mega bet on becoming a global monopoly. As of 2016 Uber had amassed € 13 billion of VC investments, while soaring to a paper-based valuation of € 61 billion. "Uber signifies a new era in tech entrepreneurship. Its leaders express an explicit ideology of domination and limitless, global ambition. In fact, the global tech sector may be one of the most powerful stateless actors on the world stage today."[352]

uncertain (grey) connections, but note that there are several other interconnected tipping elements in the climate system of the Earth that are not considered here. Abbreviation: EEP, Eastern Equatorial Pacific."

[350] Blanchard, Oliver (2015) Stop calling it the "Sharing Economy." That isn't what it is, July 29, 2015, http://olivierblanchard.net/stop-calling-it-the-sharing-economy-that-isnt-what-it-is/.

[351] Roberts, Jeff John (2015) As "sharing economy" fades, these 2 phrases are likely to replace it, *Fortune*, July 29, 2015, http://fortune.com/2015/07/29/sharing-economy-chart/.

[352] Gorenflo, Neal (2015) How Platform Coops Can Beat Death Stars Like Uber to Create a Real Sharing Economy, Shareable.net, November 3, 2015, http://www.shareable.net/blog/how-platform-coops-can-beat-death-stars-like-uber-to-create-a-real-sharing-economy.

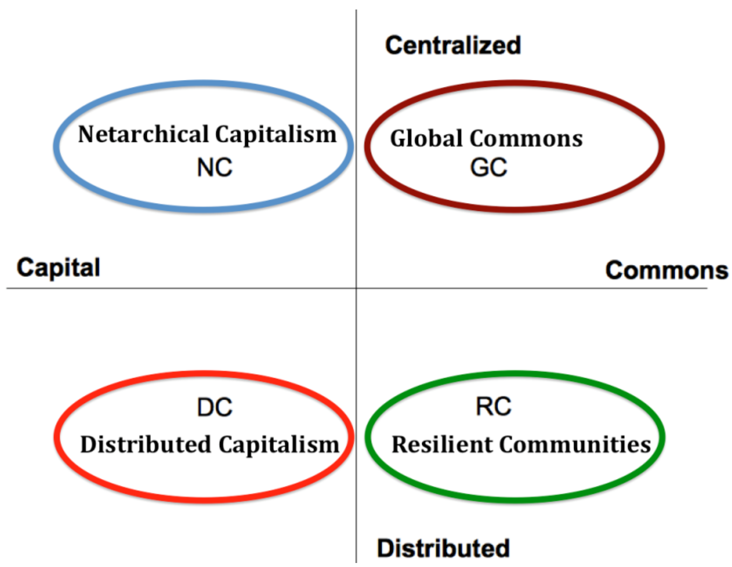


Source: Owyang, Jeremiah (2016)[353]

[353] Owyang, Jeremiah (2016) Honeycomb 3.0: The Collaborative Economy Market Expansion, Web Strategy LLC, March 10th, 2016, http://www.web-strategist.com/blog/2016/03/10/honeycomb-3-0-the-collaborative-economy-market-expansion-sxsw/.

Cooperatives offer a sharp contrast to the conventional vertically integrated market enterprise, allowing all individuals engaged in the sharing process to also share the revenue generated by the activity. Platform cooperatism is more fully fleshed out by peer-to-peer (P2P) theorists, practitioners and co-Founders of the P2P Foundation, Michel Bauwens and Vasilis Kostakis, who illuminate important distinctions between different economic and social forms of the sharing/collaborative and rental/on-demand/gig economies, in the matrix below. The two axes highlight: 1) the tensions between centralized and distributed control of the infrastructure; and, 2) the polarity between capital buildup or flow and Commons accumulation or circulation.

Four future scenarios for a collaborative economy



Source: Kostakis & Bauwens (2014)[354]

Netarchical capitalism (NC) is defined as "centralized control of a distributed infrastructure with an orientation towards the accumulation of capital. Netarchical capital is that fraction of capital which enables and empowers cooperation and P2P dynamics, but through proprietary platforms that are under central control. While individuals will share through these platforms, they have no control, governance or ownership over the design and the protocol of these networks/platforms, which are proprietary. Typically under conditions of netarchical capitalism,

[354] Kostakis, Vasilis & Michel Bauwens (2014) *Network Society and Future Scenarios for a Collaborative Economy*, Palgrave Macmillan.

while sharers will directly create or share use value, the monetized exchange value will be realized by the owners of capital."[355]

Distributed capitalism (DC) "Under this model, P2P infrastructures are designed to allow the autonomy and participation of many players, but the main focus rests on profit-making. In Bitcoin, for example, all the participating computers can produce the currency, thereby disintermediating large centralized banks. However, the focal point remains on trading and exchange through a currency designed for scarcity, and thus must be obtained through competition. As another example, Kickstarter functions as a reverse market with prepaid investment. Under these conditions, any Commons is a byproduct or an afterthought of the system, and personal motivations are driven by exchange, trade and profit."[356]

Resilient Communities (RC) focus on generating community value via "relocalization and the re-creation of local community. It is often based on an expectation for a future marked by severe shortages of energy and resources, or in any case increased scarcity of energy and resources. Initiatives like the Transition Towns, a grassroots network of communities, can be seen in that context."[357]

Global Commons (GC) focus on creating sustainable abundance for all of humanity. "Though production is distributed and therefore facilitated at the local level, the resulting micro-factories are considered as essentially networked on a global scale, profiting from the mutualized global cooperation both on the design of the product, and on the improvement of the common machinery. Any distributed enterprise is seen in the context of transnational phyles, i.e. alliances of ethical enterprises that operate in solidarity around particular knowledge Commons. In addition, political and social mobilization, on regional, national and transnational scale, is seen as part of the struggle for the transformation of institutions. Participating enterprises are vehicles for the commoners to sustain global Commons as well as their own livelihoods."[358]

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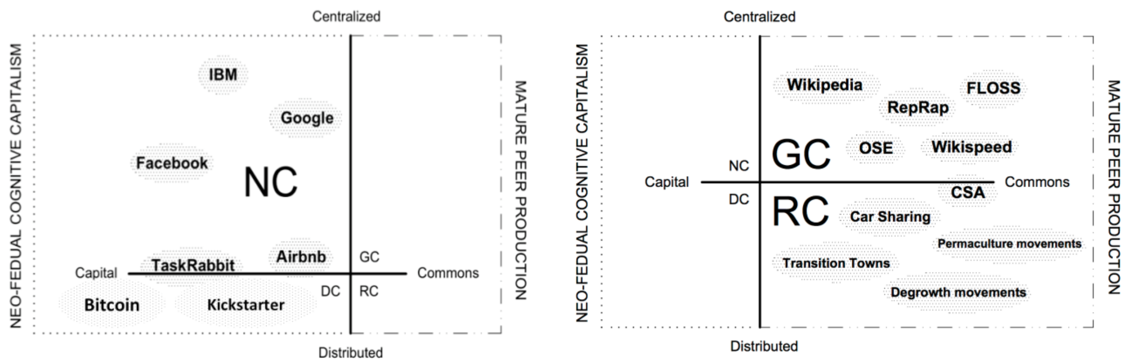
[355] Bauwens, Michel and Vasilis Kostakis (2014) Four Future P2P Scenarios, P2P Foundation Wiki, http://wiki.p2pfoundation.net/Four_Future_P2P_Scenarios.

[356] *Ibid*., Bauwens & Kostakis (2014).

[357] Araya, Daniel. *Smart Cities as Democratic Ecologies.* Springer, 20115.

[358] *Ibid*., Bauwens & Kostakis (2014).

Illustrative examples of collaborative economy



Source: Bauwens & Kostakis (2014)[359]

Perhaps most fundamentally, citizen owned and operated platform cooperatives offer business models for retaining locally created value. Cooperative models are mushrooming in the emerging Third Industrial Revolution.[360] For example, Loconomics in San Francisco is a cooperative version of TaskRabbit; Fairmondo in Germany is a cooperative version of Amazon.com; LaZooz in Israel is a cooperative ride-hailing and blockchain service alternative to Uber; Swarm is a blockchain alternative to Kickstarter; Diaspora is part of the Free Software Support Network and represents a federated social media network version of Facebook and Twitter; FairCoin is the FairCoop's open global cooperative version of Bitcoin; the open source platform sharetribe in Finland; the open value networks Enspiral in New Zealand and Sensorica in Canada; and a burgeoning number of open access libraries of knowledge resources and publications like Wikipedia, Google Scholar, Researchgate.net, Arxiv.org, Academia.edu, SSRN.com (the Social Science Research Network), and many others.

Internet platform technology is increasingly being used by citizen owned and local cooperatives. Cooperatives have a rich history of locally created value delivered locally. Worldwide, some 2.6 million cooperatives are operating, owned by its more than one billion members, employing a quarter billion people, and creating 2.7 trillion euros in yearly revenue; a revenue comparable to the 5th largest economy in the world, just after Germany. Open cooperatism, also referred to as open ethical economy, "seeks an economy where the core actors are co-operative entrepreneurs who co-produce commons and advance their goals through ethical entrepreneurial coalitions or a new type of market sector comprised of collectively oriented enterprises. One tool to advance this vision, for example, is a new set of

[359] *Ibid*., Bauwens & Kostakis (2014).

[360] Schneider, Nathan (2015) The Future of Work: Owning What We Share, September 1, 2015, https://psmag.com/the-future-of-work-owning-what-we-share-1ea682783510#.l8mfkw4qp.

"commons-based reciprocity licenses" that would enable exchange value to remain more easily within the sphere of the commons and the commoners."[361]

Renewable energy cooperatives are among the new sharing enterprises experiencing rapid growth. For example, more than 300 energy cooperatives were created in the Netherlands alone between 2005 and 2013.[362]

Regulatory, Legal and Policy Issues

As PWC succinctly notes in their 2015 report, *The Sharing Economy*, "There is no question that the regulatory, legal and tax framework needs to be fit for a new age. The right balance of solutions needs to be built from the bottom-up, where local authorities can quickly trial and experiment with new models. Not surprisingly, this is more easily done when both sides work together. For instance, Airbnb worked with Amsterdam's local council to pass an "Airbnb-friendly law" in February of 2014 which permits residents to rent out their homes for up to 60 days a year, provided that the owner pays the relevant taxes."[363]

As a number of scholars and analysts have noted, peer-to-peer businesses are changing market dynamics. This raises the need for regulatory changes, as well as enforcement and policy changes regarding competition law. Peer-to-peer businesses simultaneously create new market assets, increase the welfare of citizen consumers, spawn new job creation, add value to assets, and contribute to economic productivity. But in doing so, they also present regulatory and competitive enforcement challenges. How regulators handle these challenges is tricky, and a number of observers suggest the pursuit of outcome-focused solutions sensitive to the diverse business models.[364]

[361] Conaty, Pat and David Bollier (2014) Toward an Open Co-Operativism, A New Social Economy Based on Open Platforms, Co-operative Models and the Commons, A Report on a Commons Strategies Group Workshop Berlin, Germany, August 27-28, 2014.

[362] De Moor, Tine (2013) Homo Cooperans, Institutions for collective action and the compassionate society, Universiteit Utrecht, August 30, 2013.

[363] See: https://www.pwc.com/us/en/technology/publications/assets/pwc-consumer-intelligence-series-the-sharing-economy.pdf

[364] Fingleton, John and David Stallibrass (2015) Peer to peer businesses, regulation and competition, *Mercato Concorrenza Regole*, December 3, 2015.

Catalyzing Collaborative Innovation Networks

PROPOSALS

1 Business Model Innovation

1.1 Promote energy sharing cooperatives for each of Luxembourg's economic sectors – residential, commercial, industrial, and the farming community – in pursuit of a Luxembourg Designed 100% WWS electric powered economy. There are tens of thousands of cooperatives operating worldwide (millions of members). Cooperatives are voluntary groups, open to all citizens who desire access to a cooperative's services. Cooperatives are democratic institutions overseen by their members, who render decisions and establish policies. A cooperative's capital is democratically controlled and contributed equitably by members. Cooperatives are autonomous, self-help entities operated by their members. Cooperatives are focused on promoting the sustainable development of their communities through policies adopted by their members. Energy cooperatives have been an important option in recent decades and especially valuable in promoting distributed power generation. German, Danish, and Swedish shared cooperatives have been instrumental in the large-scale expansion of wind and solar PV systems in their nations. Expanding the use of energy cooperatives in Luxembourg is an update of the traditional sharing economy, while also incorporating the latest in high-tech, knowledge-driven opportunities for deriving value from the community's renewable energy resources.

2 Technical

2.1 **Blockchain technology should be examined as a useful tool to track prosumer/Sharing Economy activities and avoid clandestine employment.** The development of a core platform, through which all transactions relative to the Sharing Economy and prosumer activities must be included, will facilitate the task of tax authorities. Blockchain technology could be used for registering purposes, in order to build in security in value chains and record the transactions.

3 Regulatory

3.1 **Sensitize and inform prosumers about legal rights and obligation in the Sharing Economy.** When consumers also become producers – prosumers – or service providers at once, they are confronted with questions regarding product safety, consumer rights, etc., as well as commercial and fiscal issues in the Sharing Economy. To raise awareness on these important topics, prosumers must be sensitized and informed. To this end, a campaign should be launched, for example, in collaboration with the Chamber of Commerce or consumer protection organizations. The centralized web-based platform mentioned in proposal 4.7 below and intermediation websites offering services in Luxembourg are also appropriate partners to publicize relevant information on legal rights and responsibilities in the Sharing Economy.

3.2 **The State must ensure via legal guidelines and action that different business models underlie the same regulations and different operators and service providers comply with the same legal obligations**. Anticipating and recommending suitable regulations that remain pertinent in a rapidly and continuously changing environment will continue to be a substantial challenge. It is important to recognize that the Sharing Economy operates by a different set of regulatory aspirations and requirements than the traditional capital market.

While the capitalist market is based on self-interest and driven by material gain, the social Commons is motivated by collaborative interests and driven by a deep desire to connect with others and share. If the former promotes property rights, caveat emptor, and the search for autonomy, the latter advances open-source innovation, transparency, and the search for community.

What makes the Commons more relevant today than at any other time in its long history is that we are now erecting a high-tech global technology platform whose defining characteristics potentially optimize the very values and operational principles that animate this age-old institution. The IoT is the technological “soul mate” of an emerging Sharing Economy. The new infrastructure is configured to be distributed in nature in order to facilitate collaboration and the search for synergies, making it an ideal technological framework for advancing sharing across digitally operated global webs and networks.

The operating logic of the IoT is to optimize lateral peer production, universal access, and inclusion, the same sensibilities that are critical to the nurturing and creation of social capital in the civil society. As such, there is a need for both the traditional market capital model and the expanding sharing model to operate together without either being undermined.

With appropriate legislation, Luxembourg can support both consumers and businesses in Sharing Economy activities (legal certainty is a prerequisite for sound economic development). The European agenda for the collaborative economy presented by the European Commission on June 2, 2016 provides helpful guidance. The regulations would need to cover different aspects of the Sharing Economy. The distinction between professional actors and private persons operating only occasionally should be established by explicit criteria and thresholds. To ensure fair competition, professional sharing economy activities should have to comply with the same legal obligations as market economy businesses. This concerns, for instance, business permits, safety and security standards or warranty deeds, as well as fiscal and social security obligations. In addition, regulation should be designed, to create formal employment for Sharing Economy workers, where applicable, to ensure a maximum of social security. It is important to prevent the circumvention of labor laws and social standards.

3.3 Codify a right of disconnection in labor law: Mobile devices have given rise to permanent accessibility. A guaranteed disconnection right would avoid employees needing to be available even outside working hours and prevent a communication overload.

4 Public Policy

4.1 Set up Sharing Economy Commissioner. The Sharing Economy is an integral dimension of the overall economy. A core aspect of the Sharing Economy is its capacity of extracting more value from an economy's myriad assets, resulting in raising their aggregate efficiency and productivity and reducing their marginal cost and ecological footprint. Sharing cities, regions, and nations require public authorities to play leadership roles. It is essential to scale up a *public commitment to the Sharing Economy vision*, supported by all levels of government from city to national, as well as the business community, and the civil society, and backed up by the appropriate government regulations and sufficient startup capital. A new Commissioner of Prosumer/Sharing economy will take a leading role in marshaling locally supported initiatives designed to create sharing activities available for all the citizenry. Features of this Ministry include the build-out of the infrastructure essential for physical and digital sharing, providing Sharing Economy start-up and scale-up enterprises with incubation and support centers, and harnessing unused and underused public resources. The Commissioner will be tasked with the mission of developing appropriate regulations and indicators for the development and expansion of the Sharing Economy in Luxembourg. At the same time, issues raised by citizens about the prosumer/Sharing Economy need addressing. Big Data is one major issue and will even become more important over time, and opportunities and risks must be broached. These include property rights on generated data, data protection, privacy and surveillance. Another concern to monitor is the possible concentration of data in the hands of a few big operators, and what consequences could result from this situation, and which proposed actions should be developed.

4.2 The new Sharing Economy Commissioner (see 4.1 proposal) should undertake a review and evaluation of the prospect to systematically provide an individual VAT number or an entry in the register of commerce and companies to each citizen or resident. With this measure, everyone would be acknowledged as a potential social entrepreneur and prosumer. The VAT should be attached to the person, not to a specific activity, to allow dynamic prosumption, meaning the social entrepreneur could practice simultaneously or over time different activities under the same VAT number. A complementary simplification of administrative procedures would be to deposit a dossier in advance, which then would be ready for rapid activation in case of necessity when starting an enterprise.

4.3 **Document Luxembourg's Quality of Life Indicators Annually**: Set up a commission to determine the cluster of indicators encompassing quality of life measures. Set up a public platform for sharing and posting these indicators (in real-time or some proximity thereof, depending on the data gathering timeframes), as well as soliciting interaction, feedback and suggestions from citizens on how to further enhance the quality of life indicators. While much of the Sharing Economy is not counted in the GDP, sharing activities do increase the quality of life, a sense of well-being and life satisfaction. As such, quality of life indicators are as important to inform citizens as historical economic indicators that do not capture or showcase such critical benefits.

4.4 **Release "The Third Industrial Revolution Strategy Study" for Luxembourg in different languages, notably English, French, German and Portuguese**. It will be crucial to engage the whole society in the TIR transition by making Luxembourg's Third Industrial Revolution Strategy Study available in multiple languages.

4.5 **Plan a public information and discussion campaign after the release of "The Third Industrial Revolution Strategy Study."** A specific campaign should aim to raise awareness within the general public of the importance of the Sharing Economy and the involvement of all stakeholders necessary for a successful transition into the Third Industrial Revolution. The study on Luxembourg's TIR strategy should be part of a broad and fundamental public debate on the nation's economic and societal future. To support economic transition and the associated socio-cultural shift, a general communication campaign should be undertaken to familiarize the population and all socio-economic actors not only with Luxembourg's TIR strategy, objectives and motivations, but also with the general concept of TIR and its holistic approach, including underlying principles like collaborative commons, sustainability and circularity.

4.6 **Analyze Sharing Economy activities in Luxembourg.** To be able to develop well-grounded and pertinent policies, it is necessary to assess the extent and impact of Sharing Economy activities. In particular, its contribution to GDP and tax revenues, as well as the number and quality of jobs generated. These and related issues will need to be addressed in corresponding studies. The establishment of a specific inventory is a first step to providing an overview of sharing activities in Luxembourg. Additional surveys on people's motivations to participate or not in the Sharing Economy will need to be conducted to help evaluate current and projected economic, social and environmental impacts of the new modes of collaboration.

4.7 **Develop a web-based platform to operate Sharing Economy activities.** A digital platform to operate Sharing Economy activities should be developed. This could be designed as a national one-stop shop of all the things related to the Sharing Economy. First, the platform should be used to track and measure Sharing Economy activities to facilitate the task of providing essential economic statistics to the government and assessing taxes. To serve its purpose, the use of the platform should be mandatory for every participant in the Sharing Economy (intermediation websites, owners / workers, sellers / buyers, providers /users, etc.). Blockchain technology could be used as tool for registering purposes, in order to build in security in value chains and record the transactions. Secondly, the platform should be used to inform all actors of the Sharing Economy about their legal rights and obligations. Specific information should be broadcasted for each platform's operators, providers and users. Finally, the platform could be linked to the CoIN platform (see proposal 5.1).

5 Financial

5.1 **The government should take the lead in assembling a COIN platform that enables citizens to participate in the Sharing Economy:** The Sharing Economy is as much, if not more, about harnessing and leveraging human, social, civic, and intellectual forms of capital, as securing sufficient financial capital. The collaborative innovation/collective intelligence network (COIN) platform performs key educational, informational and motivational services that help build the Sharing Economy. The platform simultaneously fosters a one-stop shop of all things related to the Sharing Economy, as well as facilitates lively interaction among citizens already active in or desiring to become active in some facet of the Sharing Economy. The COIN platform should be jointly administered by government and a non-profit organization to share insights, activities, new apps, peer-to-peer exchanges, collaborative learning spaces, post queries and retrieve FAQs on specialized topics. The platform provides a continuously updated inventory of Sharing Economy activities in Luxembourg.

6 Educational

6.1 Coding (programming) should be fully integrated into the educational curriculum from an early age. Mastering code skills have been shown to be achievable by elementary school children around the world. To become adept at creating and producing applications, as well as how to knowledgeably use apps is a valuable learning exercise. This measure could stimulate young people's interest in ICT and related career opportunities. ICT is identified as a key priority economic sector in the Grand Duchy. Luxembourg has successfully developed into a global hub for information and communication technologies (ICT) and aims to position itself as a center of excellence in cyber security and data protection. The sector continuously experiences high rates of economic growth and job creation. At the same time, many companies struggle to find qualified staff.

6.2 Promote Digital savvy learning skills and competences by having students collaborate in mapping inventories of community resources. One of the most evident dynamics among digitally savvy persons is the extensive peer-to-peer learning – sharing knowledge – that occurs relative to an individual discerning the knowledge by just reading a book. Becoming digitally savvy happens most rapidly through seeing-and-doing as a result of sharing and learning. Teams raise their level of digital knowledge and know-how by swiftly circulating tips, competencies, and numerous insights-on-the-fly. Teams including a diverse mix of students with different knowledge strengths or interest predispositions also enhances peer-to-peer learning experiences; imagine a team with the following diversities: artist, strong code programmer, mechanical "gearhead" adept, electrical/electronic adept, math-finance adept, policy wonk, communication adept. The team's diversity in sharing strengths is a learning experience in itself, in addition to the know-how gains. Now augment that with the reality that students with smartphones or phablets effectively have access to pocket supercomputers capable of carrying out scores of applications. Semester by semester students can learn while contributing to their community's open source platform mappings of resource inventories. Detailed examples of what can be done are freely available on the Internet. Students can use their schools, neighborhoods, streets, parks, streams, walkways, bikeways, street lamps, tree canopies, gardens, food wastes, discharges into waterways, etc. to gather data, code apps for analyzing the data, and present insights. With the availability of low-cost wireless smart sensor networks the students can set up experiments, test hypothesizes, gather data for confirming or disproving their hypotheses, and create a dataset that can be made available open source for other students to build upon. These kinds of projects could be integrated with and/or emerge from student activities at "Makerspaces," "Science Centre Differdange," and

"Scienteenslab." Such collaborative initiatives help promote sound entrepreneurial traits by stimulating a proactive spirit, revealing personal talents and ambitions, fostering creativity and originality, as well as raising consciousness and responsibility on ecologic, social, political, and economic issues.

6.3 **Review the system of performance assessment in school.** By sanctioning errors instead of rewarding assignments done well, fundamental qualities of entrepreneurship are marginalized as students are neither encouraged to take risks nor supported to be creative or develop individual ideas. To support entrepreneurship, failures must be tolerated – a cultural change in performance assessment is desirable, if not necessary.

EXPLORING THE POTENTIAL ECONOMIC BENEFITS OF THE THIRD INDUSTRIAL REVOLUTION INNOVATION SCENARIOS

OVERVIEW

John "Skip" Laitner (Economic and Human Dimensions Research Associates), TIR Consulting Group LLC

On any given day, an office worker in Luxembourg might "telecommute" from home rather than drive to the office. At the same time, a farmer may power up a tractor to begin the harvesting of crops, while a truck driver may be on the way to deliver a replacement part that will allow a manufacturer to resume production. These separate work events all share three critical elements.

The first element is that someone undertakes an activity to get the job done. This is typically referred to as the labor component of economic activity, or perhaps skilled employment. The second is the use of machinery or some type of equipment that enables the production of goods and services. This item is the result of annual investments made each and every year in that equipment, or perhaps in the supporting infrastructure that enables all other equipment to be used. Buildings, roads, bridges, pipelines, power plants, and new installations of renewable energy technologies are all examples of supporting infrastructure. The combined investments in all of that equipment and infrastructure, as they accumulate over time, are often referred to as capital.

The third element is the high-quality flow of energy that enables work to be done—that is, the electricity, natural gas, gasoline or diesel fuel, whether they are provided by conventional fossil fuel supplies or by renewable energy resources. It is energy in the form of food that animates labor, and energy in the form of electricity or natural gas that enables capital to carry out the desired set of tasks. Depending on the mix and the productive uses of all resources that are put to work, the Luxembourg economy is able to deliver an assortment of goods and services to meet the needs of not only regional businesses and its local residents, but also to many other nations throughout the world. This so-called work is typically measured as national income or gross domestic product (GDP).

In most economic development assessments, labor and capital are often thought to be the main elements that drive economic activity. Yet, it is energy—the third, and the most often overlooked component of the economic process—that may prove to be the more critical driver of economic and social well-being. To extend our example above, a software engineer cannot develop code without electricity to power the computer. The truck driver cannot deliver a replacement part without the diesel fuel to power the truck engine. When optimally sourced and efficiently used, energy can amplify local economic development and spawn a more robust and resilient economy. But equally true, the wrong mix of those resources, and especially the inefficient use of those resources, can appreciably constrain the vitality of a local or national economy.

In 2016, the Grand Duchy of Luxembourg will spend an estimated €2 billion to meet its combined energy needs. The many payments made each day or each month will enable residents to cool and light their homes, drive to work, listen to music or watch TV, and power the country's many commercial enterprises. Electricity purchases, for example, will further enable access to the Internet, as well as filter and purify the water that is delivered to local homes, schools, and businesses every day.

Although the inhabitants of Luxembourg derive many important benefits as they pay their various energy bills, there is also a significant opportunity to save money. As we will outline later, those energy bill savings—perhaps an average of €250 million per year over the next three decades—will reduce the massive amounts of greenhouse gases and other pollutants that are released into the air. According to a recent study by Stanford University, if Luxembourg were to achieve 100 percent renewable energy by 2050, the avoided air quality health effects might be on the order of €3.04 billion per year. Moreover, the avoided 2050 global climate-change costs from converting to 100 percent renewable energy is on the order of €3.84 billion per year.[365]

There is little question that the production and use of energy holds great economic value for Luxembourg. Many renewable energy industries are growing exponentially. This is driving a positive market throughout the global economy. But as the International Energy Agency (IEA) underscores, there is also a critical need for greater emphasis on energy efficiency as well as a more diversified energy portfolio. The IEA further noted that the inefficient conversion of energy can create a large array of problems which can weaken or constrain the development of

[365] Mark Z. Jacobson, Mark A. Delucchi, et al. (April 2016). *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for 139 Countries of the World*. Department of Civil and Environmental Engineering, Stanford University. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf. Note that the original values reported here were originally expressed in 2013 US dollars. Those values were converted to Euros using a 2013 exchange rate of 1.328 USD per Euro.

a more robust economy.[366] German physicist Reiner Kümmel and his colleagues studied the economic process and noted that the economic weight of energy is significantly larger than its cost share.[367] Research by economist Robert Ayres and his colleague Benjamin Warr documented that improvements in both the quality and efficiency of delivered energy services may be the critical factor in the growth of an economy. In fact, they suggested that a greater level of energy efficiency is one of the primary forces that support meaningful technological progress, and that sustained technological progress may come only with extensive upgrades in a nation's or region's overall energy and other resource efficiency. Finally, a recent study of the EU-15, with analytical results also specific to Luxembourg, concluded that the transition to a low-carbon and more robust economy should be done in a way that ensures both the higher accumulation of capital and the more productive use of energy.[368] Both principles are wholly consistent with the pillars of the Third Industrial Revolution.

While Luxembourg boasts a more energy efficient economy than the United States and the global economy more generally, it still appears to waste more than 80 percent of its high quality energy resources. With that magnitude of ongoing energy losses each day, and also with an over-reliance on fossil fuel resources, the Grand Duchy of Luxembourg may face serious economic and competitive challenges should it continue with its current pattern of energy production and consumption.[369]

As suggested in this assessment, systematic upgrades in the use of much more energy-efficient technologies and productive investments in renewable energy systems can provide all of Luxembourg's energy needs by 2050. As also indicated, it is both technically and economically

[366] Nancy Campbell, Lisa Ryan, et al. (2014). *Capturing the Multiple Benefits of Energy Efficiency*. Paris, France, International Energy Agency.
http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf

[367] Reiner Kümmel (2011). *The Second Law of Economics: Energy, Entropy, and the Origins of Wealth*. New York, NY, Springer. See also, R. Kümmel (2013). "Why energy's economic weight is much larger than its cost share." *Environmental Innovation and Societal Transitions,* (9): 33-37.

[368] See, Vlasios Voudouris, Robert Ayres, Andre Cabrera Serrenho, and Daniil Kiose. 2015. The economic growth enigma revisited: The EU-15 since the 1970s. *Energy Policy* 86 (2015), pages 812–832.

[369] For more background and a deeper discussion on the critical link between the productive conversion of high quality energy and a robust economy, see Robert U. Ayres and Benjamin Warr (2009), *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Northampton, MA, Edward Elgar Publishing, Inc. Also see John A. "Skip" Laitner (2015), "Linking energy efficiency to economic productivity: recommendations for improving the robustness of the U.S. economy." *WIREs Energy Environ*, 4:235–252. doi: 10.1002/wene.135. For a European application of these perspectives, read Jeremy Rifkin, Benoit Lebot, J. A. S. Laitner, Solenne Bastie, Francis Hinterman and Shawn Moorhead (2013). *Third Industrial Revolution Master Plan Nord-Pas de Calais, France*. Bethesda, MD, TIR Consulting.

feasible to encourage such a transition.[370] In short, a significant portion of the billions of euros already spent each year for energy consumption can be used in other ways to more productively strengthen the country's larger economy – provided local business leaders and local policy makers choose to encourage these smarter and more productive investments.

This contribution to the master plan explores future economic development opportunities available to the Grand Duchy of Luxembourg. More specifically, the analysis examines the prospective economic returns within the Luxembourg economy if households and businesses were to shift away from current investment patterns to pursue a more productive and cleaner energy future. The analysis investigates the benefits that energy efficiency and renewable energy resources can deliver to the regional economy as the basis for a revitalized economic development. It also examines the scale of investment that will be necessary to drive those improvements. Lastly, the report details how a shift in spending toward clean energy could strengthen the nation's ability to support more incomes and jobs.

With this in mind, the next section of this assessment provides the overall framework that reinforces the analysis found here. A subsequent section then describes the current patterns of economic activity and energy consumption, and explores the scale of purposeful effort and investments that will enable Luxembourg to build up future opportunities. The last major section includes an overview of the methodology used to estimate the net job gains and other economic impacts brought on by the greater diversity in the use of energy resources and, in particular, the greater level of renewable energy and energy efficiency improvements. It then summarizes the major economic impacts of this specific inquiry and highlights the next three critical steps that can ensure a more robust, resilient, and sustainable economy within the country. The first step includes an immediate implementation of "first energy efficiency projects" to document the scale of positive outcomes that will emerge from these first ventures. The second step is to lay out a set of useful metrics that can assist in the evaluation of the benefits which follow from these and future projects. The last effort, logically building on the two previous steps, is to develop a policy-relevant database that can both track the major projects and policy initiatives and inform the nation about all of the net positive outcomes

[370] In a very thoughtful interview, San Diego Gas & Electric Senior Vice-President of Power Supply, James Avery highlighted emerging problems associated with the rapid adoption of photovoltaic energy systems. He noted: we haven't begun "to think of the technologies that will evolve" out of the digitalization of the grid. He said, the "wealth of opportunities far exceeds the programs and applications that exist today." See, http://www.utilitydive.com/news/sdge-if-youre-not-prepared-for-the-change-its-too-late/366979/. For the Grand Duchy of Luxembourg, these opportunities include both domestically-produced resources as well as cost-effective imported energy services that depend on an array of renewable energy technologies.

beyond an energy-led investment strategy. In addition, a short narrative offers further details about the economic model used to complete this assessment for the Luxembourg economy.

FRAMEWORK OF THE ECONOMIC ASSESSMENT

Properly assessing the economic impacts of different policy opportunities for the Grand Duchy of Luxembourg—what we call in this document a *Third Industrial Revolution Innovation Scenario*—is a function of perspective, data, and logic. The perspective is an understanding of how an economy can become much more productive and robust in the use of capital, materials, and especially energy. The data presented throughout the various sections of the master plan reflect the economic underpinnings of Luxembourg as well as the specific costs and benefits associated with the development and deployment of new energy service technologies, information and communication systems, transport and logistics, Internet of Things deployment, and other critical infrastructure improvements.

Rethinking the Underpinnings of the Luxembourg Economy

Luxembourg sits at a moment in history in which doing nothing is not an option. Indeed, the country finds itself at the crossroads of both challenges and opportunities. On the one hand, compared to past historical experience, the regional economy shows a lagging growth in performance. Over the period 1985-2000, for example, the amount of Gross Domestic Product (GDP) supported by each job in the Luxembourg economy—a useful proxy of economy-wide productivity—grew at a very healthy rate of a 2.6 percent annually. With a solid growth in both population and jobs, that meant the economy grew, on average, by nearly 6 percent per year over that 15-year period. Over the next 15-year period, however, the economy-wide gain in productivity was essentially flat and even a bit smaller in 2015 compared to 2000. Yet, a continuing increase in both population and jobs enabled the national economy to expand at a 2.8 percent rate per year (STATEC 2016). While significantly lower than earlier trends, this is still a healthy economic growth rate, especially when compared to the collective performance of the more than 30 countries of the Organization of Economic Development and Cooperation (OECD), which, taken as a whole, expanded by only 1.7 percent annually over that same period.[371]

[371] There is a tendency among many policy analysts to assume a reasonable and smooth projection of recent historical trends and assume such patterns will continue into the mid- to long-term terms projections. At the same time, however, there is a worrisome trend that suggests a significant weakening of future GDP. See, for example, OECD (2016), GDP long-term forecast (indicator). doi: 10.1787/d927bc18-en (Accessed on 30 July 2016). This latest data set suggests less than 2 percent growth over the period 2015 through 2060. Such projections greatly

At the same time, the key driver of the Luxembourg expansion in the last 15 years appears more to be the influx of inhabitants and workers rather than the significant increase in overall productivity.[372] And whereas standard economic projections suggest a continuing 3.0 percent annual growth through 2050 (the last year explored in the TIR Innovation Scenario time horizon), there are other forecasts and indications which suggest the possibility of a weaker and less robust level of economic activity—perhaps lowering Luxembourg's GDP to 2.0 percent or lower. This appears to be the case for the OECD region as a whole (OECD Long-Term Projections 2014).

Admittedly this last projection is a bit dated, but it is consistent with other indicators all of which point to a lagging rate in the more productive use of capital, energy and other resources. This, in turn, may hamper a more vigorous future economic activity. And if we also fold in the many steps that need to be taken to address climate change and other environmental concerns, one can quickly imagine that failure to explore these possible outcomes may leave Luxembourg, the OECD as a whole, and all of the developing nations, at risk. In this context, the Third Industrial Revolution Master Plan can be thought of in two different ways. First, "TIR-like thinking" can become an insurance plan which can enable Luxembourg to maintain a healthy economy; and second, the TIR Innovation Scenario can provide insights into the kind of new economic platform which can ensure both a resilient and sustainable economy over a longer period of time.

Notwithstanding some early warning signs of a weaker second industrial revolution economy, the Grand Duchy of Luxembourg has a number of promising opportunities that can point the way to the more productive use of its many resources; and to do so in ways that build a more robust, resilient, and sustainable economy. As described in the previous sections of the master plan, the hundreds of different opportunities range from changes in transportation land-use patterns to large-scale improvements in Luxembourg's commercial and industrial enterprises.

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underscore the need to encourage a greater and more productive investment in TIR-related infrastructure as well as both social and economic capital.

[372] In general, the growth of an economy can be thought of as the growth in the resident population or an expansion of the workforce times the productivity of that population or workforce. For example, if the number of inhabitants grew by 1 percent per year as it did between 2000 and 2015, and if the productivity of the population similarly grew by 1.8 percent annually, then the economy can be said to have expanded by about 2.8 percent over those years (which it did). We can also do a similar calculation comparing the increase of the labor market times the productivity of those workers and it would show a similar result. But the larger productivity of the Luxembourg economy is also a function of the quality and quality of the capital invested, the skills of the labor force, and we also suggest, the efficient use of resources—whether materials, production assets, and especially energy. In many ways it is this focus on energy and resource productivity that underpins the ideas of the Third Industrial Revolution Innovation Scenario.

They also include the buildup of information and communication technologies – the shift to 5G – that enable the many existing and new buildings, as well as other structures, to serve as interactive nodes that elevate and optimize overall economic performance of the Luxembourg economy. How might these options generate a net positive return compared to the standard business-as-usual assumptions? Table 1 below highlights at least seven key drivers that can support a more vibrant economy as a result of any given TIR Innovation Scenario and resulting Master Plan.

The Catalysts to a More Robust Luxembourg Economy

The first key driver is referred to as the intensity shift. Just as some energy resources are more carbon-intensive than others—for example natural gas produces less carbon dioxide per megajoule of energy than does coal while renewable energy resources produce no such emissions compared to any form of fossil fuels—different sectors of the Luxembourg economy have different income and employment intensities. More to the point, any activity or investment that fosters the development of a more productive infrastructure, that upgrades existing buildings, or that leads to the erection of new facilities—all of this done in a way that also reduces both energy consumption and energy costs—must necessarily create a shift in spending from capital-intensive energy sectors to other sectors that are generally more labor-intensive. The scale of that shift depends on a number of economic factors such as the level of imported goods and services which enables that buildout. It also depends on the magnitude of net savings. Moreover, to the extent those investments encourage larger energy savings and other productivity benefits, they will facilitate a greater level of capital deepening that facilitates a more dynamic use of capital (see Figure 1 on the following page).

Table 1. The Seven Major Drivers of Employment and Economic Benefits

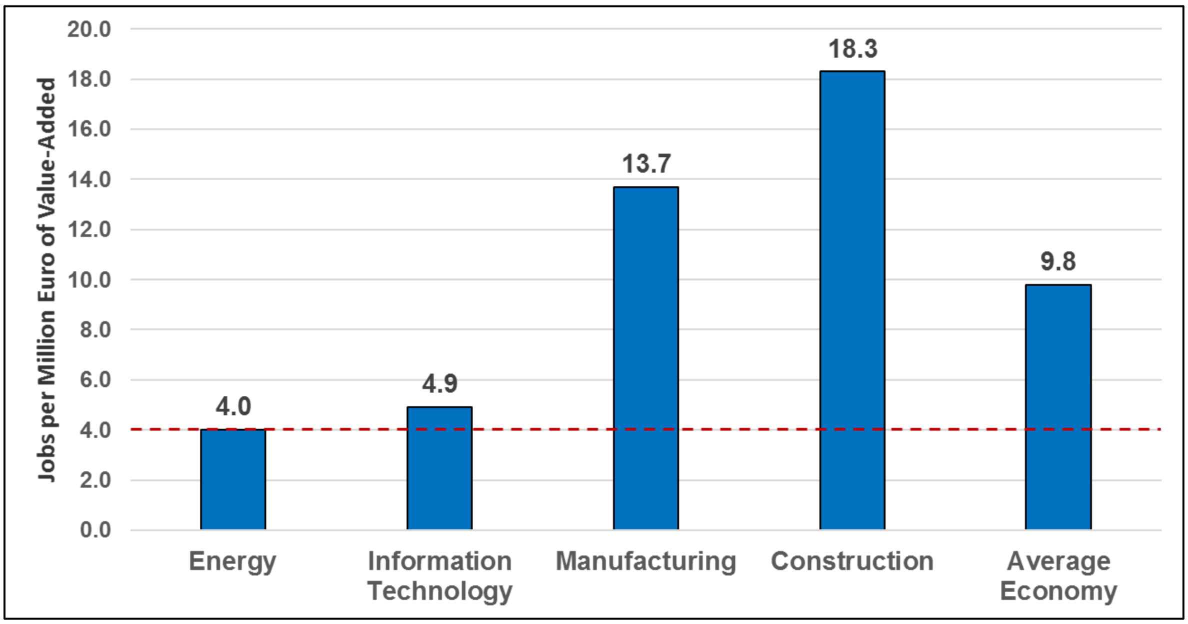
Effect	Primary Impact
Intensity Shift	Moving away from capital-intensive to labor-intensive activities
Supply Chain Build-up	Building up greater local production capacity and local services
Energy Cost Reduction	Both unit and total cost savings for efficiency and non-efficiency
Productivity Boost	Expanding non-energy benefits
Managing Volatility	Smoothing out the price shocks
Minimizing Disruption	Avoiding the inconvenient interruption of supply
Innovation Plus	Cost breakthroughs in the delivery of energy and other services

Source: As described and discussed in the text of the manuscript.

Figure 1 – based on 2013 data from STATEC – shows that energy services supported 4.0 jobs per million euros of value-added, compared to 4.9 in information and communication services, 13.7

in manufacturing, 18.3 in construction and 9.8 on average throughout the economy.[373] Hence, for every one million euros of value-added services generated through greater cost-effective energy efficiency improvements across the economy, Luxembourg will gain a net increase of 5.8 new jobs. That is, instead of supporting 4 jobs for energy purchases, the economy will be supporting an average of 9.8 jobs as the energy bill savings are re-spent for other goods and services in Luxembourg. This is a net gain of 5.8 jobs economy-wide for each million euros of a cost-effective transition away from conventional energy purchases.

Figure 1. Luxembourg Job Intensities for Key Economic Sectors



Source: STATEC Economic Accounts 2013 (Accessed March 2016).

A second category of prospective benefits results from the build-up of regional production of goods and service. While Luxembourg boasts a large export activity, it also now imports an estimated €81.5 billion in 2014 to feed its supply chain of goods and services. This is up nearly three times the level of imports recorded in the year 2000. Moreover, while Luxembourg extracts 32 percent of value-added from its total economic output, the United States by comparison pulls about 58 percent value from its total output. To the extent that a TIR master plan increases the cost-effective local production capacity for goods and services, Luxembourg

[373] This information has been provided by STATEC over the past 10 months. While STATEC has released later data since the beginning of this exercise, the changes are relatively minor in scope, and to maintain consistency with the efforts in other sections of the master plan, we continue to reference the initial data for 2013, 2014, and 2015 as originally reported.

will increase both the resilience and vitality of the national economy. As a specific example, Luxembourg now imports an estimated 97 percent of its total energy requirements. In the different energy scenarios characterized in the Energy section of the master plan, the most cost-effective future energy scenario is the one that increases the local production of electricity energy to 70 percent within Luxembourg.

Using a thought experiment, we can imagine how building up greater local capacity and energy supply from 3 percent to 70 percent can increase the robustness of the Luxembourg economy. For example, we can use a multiplier formula of [1 / (1 – 0.03)] to suggest a base economic multiplier of 1.03 for each euro spent by businesses and consumers for their overall energy needs. But if the TIR master plan moves the local purchase coefficient from 3 percent to as much as 70 percent, as suggested, then the base multiplier for energy increases to 3.33. In other words, instead of a €100 consumer purchase for average energy needs that initially might support €103 in regional activity, under the TIR master plan it would support more like €333, without incurring other additional costs to the economy. This is clearly a cost-effective improvement in well-being without any significant shift in the level of imports.[374]

A third area of opportunity is the likely positive impacts of greater resource and energy efficiencies on both energy and non-energy unit costs. Hence, even while Luxembourg can benefit from cost-effective reductions in energy and other resources, the remaining resource requirements consumption will benefit from lower total cost. For example, as suggested in Table 4, rather than an anticipated cost of €1,330 per kilowatt of a rooftop photovoltaic system in 2015, an expanded market with economies of scales and scope is anticipated to drive the costs down to as low as €660 per kilowatt. In this scenario, a greatly expanded market can drive further material and design innovations that can lower other costs as well. A related fourth area of benefit is the prospective of greater productivity which can expand economic opportunity even given the same level of resource consumption. As an example here, Luxembourg's GDP in 2014 was an estimated €49.4 billion. Had the larger productivity of the nation's economy been just 0.5 percent higher over the period 2000 through 2014, Luxembourg's GDP would have been €3.6 billion larger. Again, checking Figure 1 on the jobs per million Euro, a €3.6 billion gain in that higher productivity would have led to higher employment of about 35,000 jobs (all else

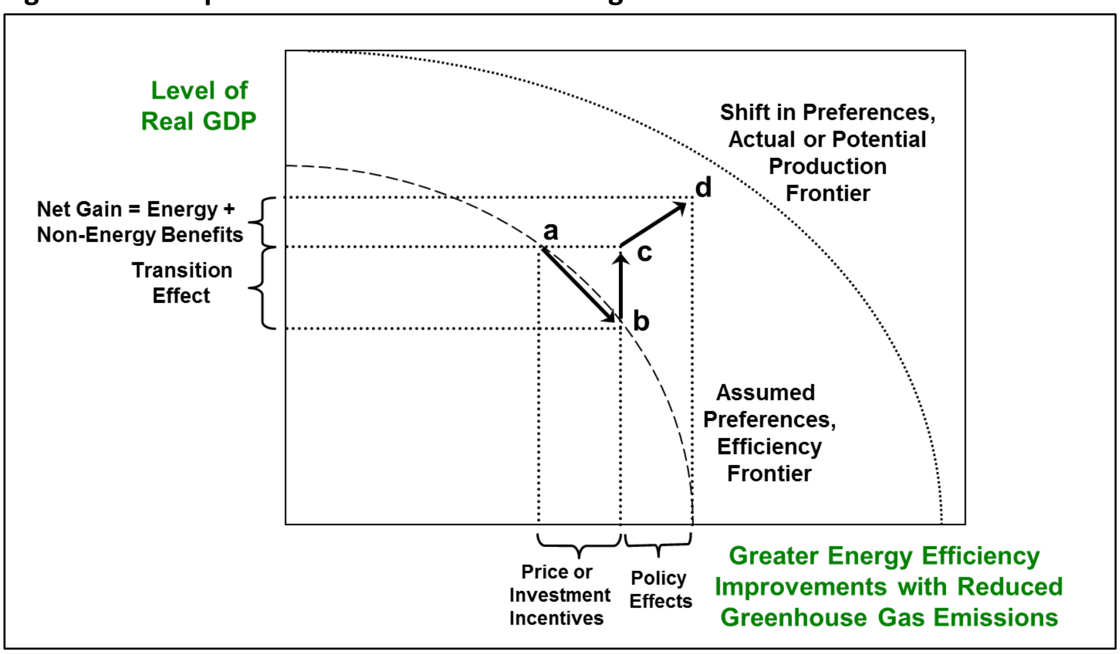
[374] This example is intended to show only the relative impacts of increasing the local production of Luxembourg's energy needs. There are other interactions that will affect, either up or down, the actual net impacts of these changed purchase patterns. Among these other drivers are the actual mix of energy resources that are produced locally, the amount of capital borrowed from Luxembourg versus European or other investors, the scale of home-grown ancillary services necessary to support local production, and the magnitude of local wages versus outside employment or contractor support services.

being equal). In effect, €3.6 billion is 3,600 million times 9.8 jobs per million Euro which equals 35,000 more jobs.

A fourth and fifth set of impacts include managing the disruption in the availability of energy and other resources while also minimizing the unexpected effects of price volatilities. As the demand for goods and services is reduced in Luxembourg, the EU-28 and the global market more generally, compared to the desired or necessary levels of jobs and incomes, and especially the need for imported resources is reduced, the Luxembourg markets will enjoy reduced exposure and therefore a greater certainty in the availability of resources. Finally, the seventh major driver of greater employment and economic benefits that are likely to follow from the TIR Innovation Scenarios is the continuous learning and encouragement which will catalyze greater innovations, whether the development and deployment of new general purpose technologies, or the innovative changes in business models that can satisfy social, economic, and environmental needs within the Grand Duchy of Luxembourg.

Figure 2, immediately below, provides a conceptual framework that helps pull the TIR Master Plan and Innovation Scenario into a useful perspective. While we cannot know at this time either the scale of the stimulus, the productive impact of the many positive collaborations that will be necessary, or the precise outcomes that might result from such innovations, we can offer a positive general explanation of how multiple benefits are likely to emerge through the TIR Master Planning Process.

Figure 2. Conceptual Framework for Evaluating TIR Innovation Scenarios



Source: John A. "Skip" Laitner (May 2016).

Given their very hectic and busy work and travel schedules, many business and political leaders understandably do not have the time to think through how the economy is operating across the larger dimensions of climate and energy policy. And the assumption might typically be made that Luxembourg is on what is called a production frontier at point “a” in the Figure 2 diagram above. Given the current market structures, technologies and social needs, any change to satisfy a demand for greater efficiencies, or for the reduction in greenhouse gas emissions, must likely result in a downward shift to the right on this graphic illustration. Basically, Luxembourg might achieve some mix of isolated productivity improvements, and there might be some reduction in greenhouse gas emissions, but it must surely come at the cost of a reduction in incomes and GDP. Yet the TIR Innovation Scenario envisions a revitalized thinking, together with a set of programs, policies and incentives that may initially drive the economy down to point “b”. Yet, such a shift may also create a productive transition that can lift the economy to point “c.” The result might be an improvement in energy efficiencies (as well as the more productive use of resources more generally) even as the economy remains at a relatively stable level of GDP.

At some point, however, the various energy and non-energy benefits that result from an array of incentives and policy initiatives can boost the performance of the economy to a higher than expected level of performance. Although not drawn to scale in Figure 2, the migration from point “a” to the eventual point “d” might represent a 30 percent reduction in energy requirements per unit of GDP together. The net energy savings together with a transition to a renewable energy system might, in turn, stimulate net gains in jobs and GDP (as we shall see when we turn our attention to Tables 6 and 7 later in this section of the master plan). Equally critical, the TIR Innovation Scenario can become a way to catalyze the seventh benefit of such master plans—an enhanced push of the production frontier so that future technologies and markets are encouraged, developed and implemented to the long-term benefit of the economy.[375]

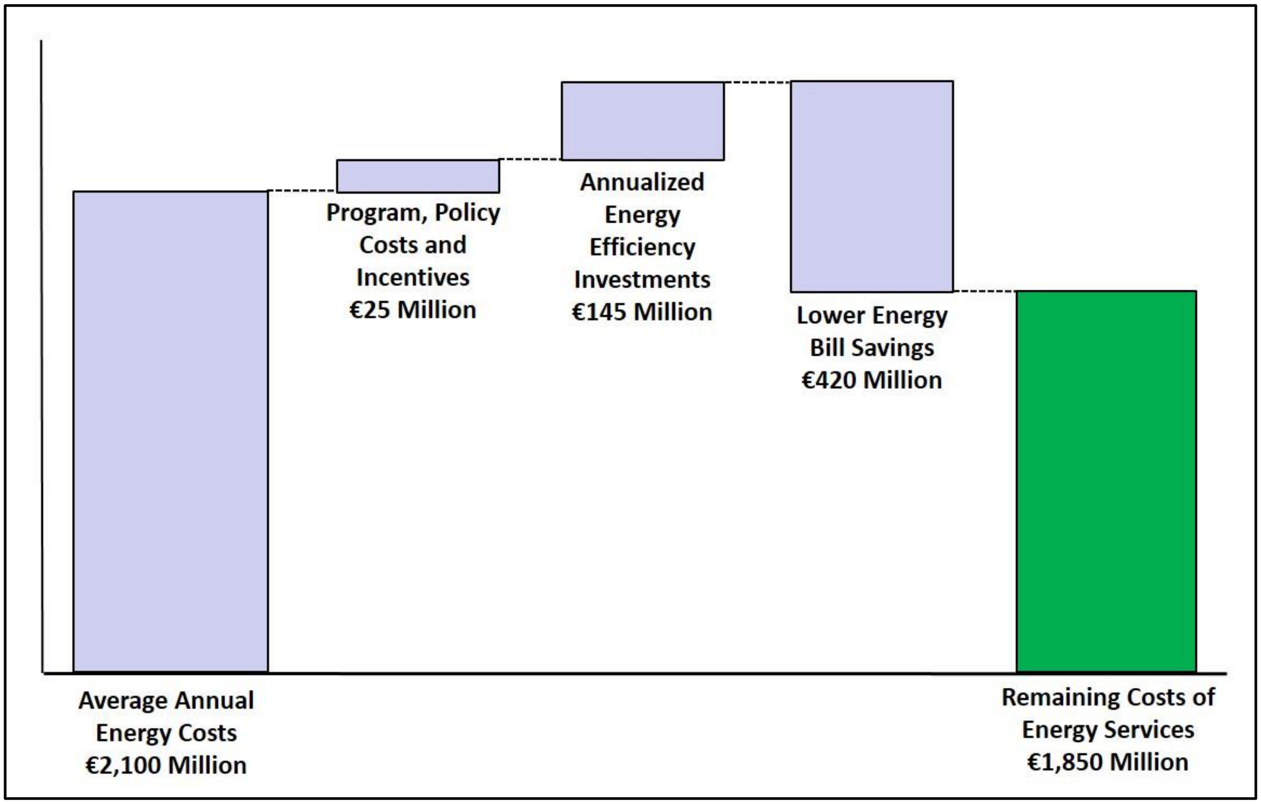
[375] It is true that a one or two percent absolute improvement over any long-term forecast may seem a very small benefit. In that regard, the roughly €2 billion net gain in GDP suggested in this assessment, compared to a reference case projection of more than €100 billion, may seem less than appealing. Yet, equally important is understanding that the “movement to” and the “outward movement of” the production frontier can provide a sustainable basis to ensure a 3 percent growth in GDP rather than the prospect of a lagging growth rate of 2 percent growth rate. Indeed, that may be among the more important outcomes of the TIR master plan. For instance, the mere subtraction of a 1 percent from a 3 percent growth rate can mean an economy that is 30 percent smaller by 2050. The OECD is sufficiently concerned about lagging productivity worldwide, including both Luxembourg and the United States, that it released a special study on this topic. See, *The Future of Productivity*, OECD Publishing, Paris, 2015. http://dx.doi.org/10.1787/9789264248533-en.

Because this idea is central to the advancements envisioned by the TIR master plans, Figure 3 that follows provides yet another glimpse of the potential economy-wide benefits which are likely to result from a lower cost of energy services. As we look forward to information provided in Table 2, Luxembourg appears to have an aggregate annual energy bill of about €2,100 million (reflecting data from the annual accounts for the year 2015). Looking even further ahead at Table 6, we find that the TIR Innovation Scenario (described more fully below), over the period 2016 through 2050, might generate lower annual energy costs of €1,680 million. This results in an initial energy bill savings of about €420 million.

At the same time, to enable the savings requires that Luxembourg create a series of programs, policies, and incentives which might average about €25 million per year.[376] It is these initiatives that, in turn, will drive the requisite large-scale of investments which are amortized over time as one might pay for a new home or building. Since the renewable energy technology costs are part of the average annual energy supply expenditures, it is only the annualized energy efficiency investments that further bump up the cost to an estimated €145 million (also reflecting average annual payments for those relevant investments over time). All of this means that, although gross savings might be €420 million each year on average, paying for the additional energy efficiency investments over time, as well as for the annual cost of programs and policies, reduces the gross savings of €420 million to a net savings of €250 million. The first result in exploring the costs of energy services is a lower €1,850 million total cost per year.

[376] This figure reflects expenditures within the public, private, and non-profit sectors to educate, train, market, promote and evaluate the relevant programs and policies which will be necessary to elevate the performance of the Luxembourg economy.

Figure 3. The Average Annual Payments for Energy Services, 2016 through 2050



Source: John A. "Skip" Laitner (September 2016).

As beneficial as this outcome appears to be, it is merely the result of a lower total cost of energy-related resources. We can also account for other social, economic, health, and environmental costs that will also impact Luxembourg. Again recalling the country-specific impacts from the Stanford University study noted earlier,[377] if Luxembourg were to achieve a 100 percent renewable energy economy, the combined avoided air quality health effects and global climate-change impacts might approach €7 billion in further savings by 2050. This does not include further GDP and employment benefits that are likely to accrue from the more productive pattern of infrastructure investments, energy efficiency upgrades, as well as the deployment of large-scale renewable energy systems.

Here we might imagine changes like the transportation land-use patterns, the buildup of information and communication technologies and a multitude of other infrastructure changes which underpin the Communication Internet, the Renewable Energy Internet, and the Transportation and Logistics Internet, as well as the various buildings and other structures that will be transformed into IoT nodes to optimize overall economic performance of the

[377] Referencing Jacobson, Delucchi et al. (2016).

Luxembourg economy. Such an outcome then becomes an opportunity for a mix of more productive investments to reduce the total cost of energy services so that any remaining net costs are substantially smaller than a business-as-usual assumption. The important element in all of this is that, if Luxembourg is to maintain a robust economy, there must be some combination of greater connectivity and interoperability coupled with new resource and material efficiencies to reduce the real cost of energy services in each successive year, from today through the year 2050. The scale of the opportunity is significantly greater than traditional economic models might otherwise indicate.

For example, there have been five major published studies in the past few years by the American Council for an Energy-Efficient Economy (ACEEE), Cisco, General Electric, McKinsey, and AT Kearney, all speaking to the enormous potential in terms of increased efficiencies productivity, new business models, and employment opportunities brought on by the shift to an Internet of Things smart economy. The 2014 assessment by ACEEE concluded that accelerated investments in ICT-enabled networks could lead to productivity benefits that would create a $79 billion energy bill savings in the United States, even as the economy expanded by as much as $600 billion.[378] Cisco systems forecasts that by 2022, the Internet of Everything will generate $14.4 trillion in cost savings and revenue.[379] A 2015 McKinsey report entitled, "The Internet of Things: Mapping the Value Beyond the Hype," suggests that the build out and scale up of an Internet of Things infrastructure will have a 'value potential' of between $3.9 trillion to $11.1 trillion per year by 2025.[380] A General Electric study concludes that the efficiency gains and productivity advances made possible by a smart industrial Internet could resound across virtually every economic sector by 2025, impacting “approximately one half of the global economy.”[381] A 2016 AT Kearney study entitled, "The Internet of Things: A New Path to European Prosperity," says that "over the next 10 years, the market for IoT solutions will be worth EUR 80 billion, and the potential value for the EU28 economy could reach EUR 1 trillion." The report goes on to say that the increase in productivity alone could exceed EUR 430 billion in

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[378] John A. “Skip” Laitner Matthew T. McDonnell Karen Ehrhardt-Martinez. 2012. The Energy Efficiency and Productivity Benefits of Smart Appliances and ICT-Enabled Networks: An Initial Assessment. Washington, DC: American Council for an Energy-Efficient Economy. http://aceee.org/blog/2014/11/internet-everything-could-be-huge-boo.

[379] Shane Mitchell, Nicola Villa, Martin Stewart-Weeks, and Anne Lange. 2013. The Internet of Everything for Cities: Connecting People, Process, Data, and Things to Improve the ‘Livability’ of Cities and Communities. Cisco. http://www.cisco.com/c/dam/en_us/solutions/industries/docs/gov/everything-for-cities.pdf

[380] James Manyika, Michael Chui, Peter Bisson, Jonathan Woetzel, Richard Dobbs, Jacques Bughin, and Dan Aharon. 2015. The Internet of Things: Mapping the Value Beyond the Hype. McKinsey Global Institute. http://sensorcommtech.com/the-internet-of-things-mapping-the-value-beyond-the-hype-mckinsey-global-institute/

[381] Peter C. Evans and Marco Annunziata. 2012. Industrial Internet: Pushing the Boundaries of Minds and Machines. General Electric. https://www.ge.com/docs/chapters/Industrial_Internet.pdf

the EU.[382] Based on a per capita allocation, that could mean a EUR 483 million boost for Luxembourg. However, AT Kearney is quick to add that the increased capabilities brought on by the digitalization of the infrastructure will "increase exponentially when connected objects are coordinated."

What is common to all of these reports, as well as our own study for Luxembourg, is that these "potential scenarios" become quantifiable when applying a new set of metrics tailored to the build out and scale up of the interoperable Third Industrial Revolution general purpose technology platform. As the ACEEE study commented, "the data now generally collected do not track either energy efficiency or productivity improvements driven specifically by the Internet or by smart appliances and ICT-enabled networks." Hence, the importance of developing new metrics and new analytical techniques to evaluate and highlight future opportunities.

The moment the digital infrastructure evolves, real-time data, based on the metrics employed, will begin to provide a valuable dataset on the gain in aggregate efficiencies and productivity and the reduction in ecological footprint and marginal cost that can guide future investment decisions. As the infrastructure becomes increasingly interoperative, creating a multitude of cross-sector synergies—just as was the case during the First and Second Industrial Revolution—the dataset will become increasingly robust and provide increasingly accurate information from which to make future decisions on the continued build out and scale up of the digital ecosystem.

COMPARING THE REFERENCE CASE AND THE TIR INNOVATION SCENARIOS

Beginning in the late 1960s and early 1970s, Royal Dutch/Shell developed a technique known as ''scenario planning.'' Rather than attempting to forecast a precise estimate of the global business environment, the intent was to create a series of narratives—the so-called *Rivers of Oil* scenarios—to help Shell's management anticipate the eventuality (if not the timing) of future oil crises. The scenario building proved to be an effective tool. Armed with foresight, and with

[382] Thomas Kratzert, Michael Broquist, Hervé Collignon, and Julian Vincent. 2016. The Internet of Things: A New Prosperity to European Prosperity. ATKearney.
https://www.atkearney.com/documents/10192/7125406/The+Internet+of+Things-A+New+Path+to+European+Prosperity.pdf/e5ad6a65-84e5-4c92-b468-200fa4e0b7bc

an agility and internal capacity to respond to the 1981 oil glut, Shell sold off its excess before the glut became a reality and prices collapsed.[383]

The question we want to ask in Luxembourg is how TIR Innovation Scenarios, based on the build out of a more robust and sustainable Third Industrial Revolution infrastructure and accompanying business models, might compare with a typical or standard projection of the nation's GDP growth compared to a conventional Second Industrial Revolution platform. To begin that comparison, Table 2 summarizes key reference case energy and economic variables over the period 2015 through 2050 for the benchmark years 2015, 2017, 2020, 2030, 2040 and 2050.

Table 2. Luxembourg Reference Case Projection for Key Energy and Economic Variables

	Metric	2015	2017	2020	2030	2040	2050
Population Growth	Inhabitants	576,192	596,303	627,794	745,278	884,746	1,050,315
GDP	Million $Euros_{2000}$	39,793	42,246	46,211	62,322	84,048	113,349
Total Energy Demand Reference Case	GWh	25,419	25,426	25,437	25,473	25,509	25,545
Reference Case Energy Expenditures	Million $Euros_{2015}$	1,997	2,008	2,024	2,077	2,133	2,190

Source: STATEC data/projections with results from the Fraunhofer Institute KomMod Model (July 2016).

The base year, or starting point, of this analytical exercise is 2015. The analysis assumes the year 2017 is the first active investment in TIR-related investments. The four decadal years of 2020, 2030, 2040 and 2050 provide further data and key results. According to 2015 statistics available from STATEC, the Grand Duchy of Luxembourg had an estimated 576,192 inhabitants within its borders. Current projections show a population growth rate of 1.73 percent per year. This means that the population will nearly double to 1,050,315 persons by 2050. That large increase in the number of inhabitants is expected to drive GDP further, from just under €40 billion in 2015 to a significantly larger economy of €113 billion by 2050, an annual growth rate of 3.04 percent over that time horizon (with both values expressed in real 2000 Euros rather than nominal terms).[384] At the same time, building on energy consumption patterns reported

[383] The development of the Shell scenarios was led by Pierre Wack, an economist, who was then the head of the business environment division of the Royal Dutch/Shell Group planning department from 1971 to 1981. For a deeper review of these early successful efforts in scenario planning, see: Wack, Pierre. 1985. Scenarios: Uncharted Waters Ahead. *Harvard Business Review*. No. 85516. September-October, pages 72-89.

[384] Since the results from the TIR Innovation Scenarios were first developed, STATEC updated key projections highlighted in Table 2. Population in 2050 was projected to be 1,057,798—a 0.71% increase shown Table 2. GDP was reported to be 0.07% higher. These changes are so very small that, rather than spend further time and effort to update all such results, the decision was made to continue with the July 2016 outcomes. Consistent with the philosophy of Stanford University's Energy Modeling Forum, we are modeling for insights rather than precision—or in this case, evaluating reasonable differences between reference case assumptions as we explore prospective benefits of the TIR Innovation Scenario for Luxembourg. See, Huntington, Hillard G., John P. Weyant, and James L.

by the Fraunhofer Institute for Solar Energy Systems ISE (located in Freiburg, Germany), total energy consumption is estimated to be 25,419 Gigawatt-hours (GWh) in 2015. Because of various energy policies and programs now in place, together with expected market trends,[385] the overall energy efficiency of the Luxembourg economy in the reference case is expected to approach 3 percent per year which will offset any significant growth in total energy consumption. This is a significant rate of improvement, compared to, for example, the one percent rate of improvement seen globally over the last decade or so. The end result is that Luxembourg's total reference case energy demands in 2050 are anticipated to be nearly identical to those in 2015, at about 25,545 GWh.[386] As prices increase slightly (in real 2015 Euros) through 2050, the reference case projection suggests that total energy expenditures will increase from just under €2 billion in 2015 to just short of €2.2 billion by 2050.

At this point there are several questions that can be asked, including: (1) how much more energy efficiency improvements are possible; (2) how much of the remaining energy demands can be met by an array of renewable energy technologies (whether wind, solar photovoltaics, solar heating, and biomass resources); and 3) how much might all of this cost? In such a case it is often helpful to begin with a thought experiment to provide a working estimate of magnitudes. Table 3 below highlights this first approximation to begin to answer these three questions.

In collaboration with the Ministry of the Economy and others within STATEC, the Fraunhofer Institute laid out what is called the Ambitious Energy Efficiency (AEE) scenario, or what we call here the "TIR Innovation Scenarios."[387] That assessment determined that it would make

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Sweeney. 1982. Modeling for Insights, Not Numbers: The Experiences of the Energy Modeling Forum. *Omega: The International Journal of Management Science* 10(5): 449-462.

[385] For example, see the discussion of Energy Efficiency Trends and Policies in Luxembourg (January 2016), at http://www.odyssee-mure.eu/publications/national-reports/energy-efficiency-luxembourg.pdf

[386] There are several items that might be worth commenting on. First, a GWh is generally a unit of measure for electricity consumption. Nonetheless, all forms of energy—whether natural gas, coal, oil, conventional electricity, or even renewable energy technologies—can be expressed in terms of their equivalent heat value, and then converted to an equivalent GWh total. For example, 1 GWh is the equivalent to 86.04 tons of oil (toe). For this exercise, the Fraunhofer Institute has provided the GWh as the metric of use in this discussion. The 25,419 GWH of total energy demand in 2015 is a sum of total electricity demand in Luxembourg of 5,895 GWh, various demands for heat at 13,322 GWh, and local personal transportation energy requirements of 6,202 GWh equivalent. These totals do not consider the need for fuel tourism, transit, and aviation.

[387] See, for example, the discussion and Table 2 results in the Energy section of the master plan which summarizes the final energy demand for 2015 and the projections for 2050. The discussion that follows here integrates the findings of Fraunhofer ISE presented to the Luxembourg Working Group on 5 July 2016, entitled 'Results of Energy System Modelling of Luxembourg' and the energy sub-report, 'Results of Modelling the Energy System of Luxembourg.' Fraunhofer ISE, 27 July 2016.

economic sense to reduce overall energy demand from 25,545 GWh in 2050 down to 16,977 GWh at that time—a one-third reduction compared to the reference case forecast. As shown in Table 3 that follows, this implies an energy efficiency savings of 8,568 GWh, with the remaining energy needs provided through a mix of renewable energy technologies. Equally important, Fraunhofer included a number of sensitivity cases to determine an optimal level of renewables that might be provided within Luxembourg. The analysis indicated that Luxembourg did have the technical potential for an energy system in which 100 percent of the country's demand is generated within the nation's borders. At the same time, however, the more cost-effective scenario is one in which only 70 percent is locally generated and 30 percent is imported from neighboring countries. The results are summarized in Figures 4 and 5 in the Energy section of the Strategy Study.

Table 3. Suggested Investment Scale for the TIR Innovation Scenario in Luxembourg

	GWh Demand	Assumed Investment €/GWh	Total Investment Billion €
Starting Energy Demand 2050	25,545	-	
Suggested Efficiency Gains by 2050	8,568	600,000	5.1
Renewable Energy Technologies by 2050	16,977	1,300,000	15.4
Total Energy-Related Capital Costs	-	-	20.6

Source: A thought experiment drawn from various sources as described in the text. The assumption is that only 70 percent of renewable energy generation will be deployed in Luxembourg.

But the question remains, how much investment might we imagine will be required to achieve the energy efficiency and the renewable energy targets of the overall TIR Innovation Scenario? Again turning to Table 3, there are two working estimates of investment per GWh that can provide an initial calculation. The first suggests an average energy efficiency cost of €600,000/GWh over the 35-year time horizon. If, for example, we assume a 3 percent interest payment over a 20-year period, that would suggest an average annual cost of 4 € cents (€ct) per kilowatt-hour (kWh). By comparison, industry now pays about 8 €ct/kWh for the electricity that it uses, while households pay about twice that much. On the other hand, the cost of photovoltaic energy systems—used here as a proxy for the full array of potentially available renewable energy technologies—might be about twice that magnitude, or €1,300,000/GWh. Following the previous logic for energy efficiency, the amortized cost might run about 9 €ct/kWh. These investment estimates are in general agreement with the published literature, and in consultation with members on the TIR Core Consulting Team.

Multiplying the two cost estimates by the Fraunhofer benchmark energy savings or production by 2050 indicates a preliminary investment requirement on the order of €20.6 billion over the 35-year period of analysis. At this point we can now begin to compare the working example in Table 3 with published statistics made available through the Fraunhofer Institute's KomMod modelling system as shown in Table 4 that follows.[388] In sum, Table 4 highlights 15 different technologies that can be used to provide a secure and reliable energy source for a variety of home and business needs. By way of explaining the table, rooftop solar suggests a 2015 investment cost of €1,330 per kilowatt of rooftop photovoltaic capacity in 2015. As previously mentioned in the Table 1 discussion, with anticipated improvements in materials and design, Fraunhofer suggests costs will decline to about €660/kilowatt. This change over time may be sufficient to reduce delivered costs of electricity from about €ct 10/kWh in 2015 to perhaps €ct 5/kWh by 2050. These costs also include annual operating and maintenance systems necessary to maintain a reliable and safe operation.[389]

Table 4. Technology Cost Assumptions for TIR Innovation Scenario

Technology	Lifetime (Years)	Investment Cost (€2015/kW)		
		2015	2030	2050
wood boilder	20	510	533	565
solid biomass chp plant	30	1,428	1,493	1,583
biogas chp plant	12.5	421	440	466
liquid biofuels chp plant	12.5	421	440	467
rooftop photovoltaics	25	1,330	921	660
free field photovoltaics	25	1,209	837	600
solar heat	25	1,286	777	396
wind power plant	20	999	1,044	1,107
heat pump air-water	20	1,243	1,243	1,243
heat pump brine-water	20	1,492	1,492	1,492
heatpump geothermal probe	20	1,467	1,467	1,467
hydro station	60	3,300	3,452	3,505
power to heat	20	238	238	238
Li-Ion battery*	15	1,558	1,006	666
thermal storage*	20	102	106	113

Source: Fraunhofer Institute ISE (2016). Note: items with asterisks are costs per kWh.

[388] See also the extended discussion of energy resource costs in the Energy section of this master plan and the investment costs and returns from the Luxembourg Sustainable Energy Finance Program, also found in this master plan.

[389] It is worth noting that the costs of photovoltaics, as suggested elsewhere in this master plan, may already be approaching 55 US cents per watt by 2017, or about €492 per kilowatt (at current rates of currency conversion). Hence, the results reported here are likely conservative. That is, the costs are higher than what we might expect from the future market. Net economic benefits reported here may be understated.

How all of the changes in demand and supply add up over time, together with their associated costs to deliver the necessary energy services are summarized in Table 5, which shows three key variables for two different scenarios. First, it highlights key cost variables for what is labeled as REFERENCE 2050, or the main Reference Case assumptions out to the year 2050. The four primary indicator variables are: (1) the life cycle cost of heat energy (LCOE) in €ct per kWh; (2) the LCOE for electricity (also in €ct per kWh); (3) the LCOE for transport fuels (again in €ct per kWh); and finally (4) the total energy costs in the year 2050 expressed in € Million per year. All costs reflect constant $€_{2015}$ values. The same results are then shown for the TIR Innovation Scenario, also for the year 2050.

Table 5. Unit and Annual Cost Assumptions for TIR Innovation Scenario

Resource	Cost Unit	REFERENCE 2050	TIR 2050
LCOE heat	$€ct_{2015}$/kWh]	6.55	6.99
LCOE electricity	$€ct_{2015}$/kWh]	6.97	7.10
LCOE Transport Fuels	$€ct_{2015}$/kWh]	11.99	13.31
Total Annual Costs	$€_{2015}$ Mio/year]	2,190	1,369

Source: Adapted from Fraunhofer Institute ISE (2016).

Three things stand out from the information provided in Table 5. First, the unit energy costs for heat, electricity and transportation fuels are somewhat more expensive in the TIR 2050 Innovation Scenario compared to the 2050 Reference Case Scenario. Second, from the standpoint of the larger demand for energy services, however, this is still a positive result. The reason is that total energy costs in TIR 2050 are significantly lower compared to the Reference Case projections. The positive result is made possible by the savings from the other investments in generating a more energy-efficient economy. The Reference Case 2050 total energy costs are listed as €2,190 million in Table 5, so that even with the higher unit supply costs (that is, the higher €ct per kWh), the total energy costs of the TIR Innovation Scenario are significantly less at €1,369 million.[390] Finally, and although not shown in Table 5, the optimal TIR Innovation Scenario, in which 70 percent of renewable resources are produced within Luxembourg, provide unit energy costs that are about 20 percent less expensive than if 100 percent of the renewables are generated within the region. The Table 5 results then show the reduced total cost from less expensive energy efficiency improvements as well as an optimal level of in-region production of renewable energy generation.

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[390] A minor note: The Reference Case 2050 results for the total energy costs, listed here at €2,190 million, differ from Fraunhofer's original cost of €2,007 million (all in 2015 real Euros). The reason is a small price increase that increases slowly over time compared to the prior assumption of a steady price from 2015 through 2050. However, neither assumption changes the overall outcome of this analysis.

Table 6 that follows provides a more complete "scenario context." The Reference Case assumptions include a current combination of fossil fuel energies alongside a small amount of renewable energies. By contrast, the TIR Innovation Scenario includes a vast increase in energy efficiencies alongside an ambitious shift to renewable energies to allow Luxembourg to achieve 100 percent renewable energy capacity, again, 70 percent of which will be generated domestically, and the other 30 percent transmitted into the country from surrounding nations by 2050.

Table 6. Illustrative Outcomes for Luxembourg's TIR Innovation Scenario

	Metric	2015	2017	2020	2030	2040	2050	Annual Average 2016-2050
Population Growth	Inhabitants	576,192	596,303	627,794	745,278	884,746	1,050,315	
GDP	Million Euros$_{2000}$	39,793	42,246	46,211	62,322	84,048	113,349	
Total Energy Demand Reference Case	GWh	25,419	25,426	25,437	25,473	25,509	25,545	
Reference Case Energy Expenditures	Million Euros$_{2015}$	1,997	2,008	2,024	2,077	2,133	2,190	2,100
TIR Innovation Energy Demand	GWh	25,419	25,122	24,243	21,528	19,118	16,977	-
Energy Efficiency Gain	GWh	0	304	1,194	3,944	6,391	8,568	-
Existing Energy Supply	GWh	25,419	25,022	23,293	15,329	7,529	0	-
Increments of New Renewable Energy	GWh	0	100	950	6,200	11,588	16,977	-
TIR Innovation Net Energy Bill Savings	Million Euros$_{2015}$	0	-14	52	197	350	485	250
Gross Energy Bill Savings	Million Euros$_{2015}$	0	0	96	334	575	821	420
Program, Policy, Transaction Costs	Million Euros$_{2015}$	0	8	16	33	24	19	25
Energy Efficiency Payments	Million Euros$_{2015}$	0	7	27	105	200	317	145
Energy Supply Expenditures	Million Euros$_{2015}$	1,997	2,008	1,928	1,743	1,558	1,369	1,680

Source: STATEC, OECD data/ projections and DEEPER model simulations.

To better orient the reader, first note the row that is labeled TIR Innovation Energy Demand, and then note the initial energy demand of 25,419 GWh listed in the year 2015. This is also referenced two rows down under the listing of Existing Energy Supply. As the energy efficiency investments kick in, beginning in 2017, and the Increments of New Renewable Energy (effectively, the array of renewable energy technologies listed in Table 4) begin to penetrate the market, the need for the Existing Energy Supply slowly drops to near 0 GWh by 2050.

A Side Note on the Job Creation Potential in Luxembourg

Table 1 in this section offered a useful context to understand the seven different economic and employment drivers that underpin the transition to the Third Industrial Revolution. At this point, however, it is useful to draw on estimates from other segments in the master plan to offer concrete examples of how TIR-related investments might positively impact future employment gains. For example, Germany's vast experience in retrofitting buildings provides a useful insight for the job creating potential in Luxembourg as it embarks on its own nationwide retrofitting project. To date, as reported in the Buildings section of the master plan, 342,000 apartments have been retrofitted, creating or saving more than 141,000 jobs in Germany.

Looking across more of the European economy, a 2011 analysis by the Buildings Performance Institute Europe (BPIE) suggested a potential energy savings in EU buildings ranging from 32 to 68 percent by 2050, depending on the scope and scale of upgrade investments. The investment cost might range from €343 to €937 billion, with a net consumer bill savings from €160 to €381 billion over the period 2012 through 2050. The combination of investments and net energy bill savings might drive a net annual employment gain of 500,000 to 1.1 million jobs (see, Table 1 in the Buildings section of the master plan).

The Stanford/UC Berkeley study noted that with a combination of energy efficiency improvements and the deployment of solar and wind renewable energy resources, by 2050 Luxembourg could meet nearly 100 percent of its energy needs by renewable energies alone. For example, of that total renewable energy supply, 67 percent of Luxembourg's energy needs could be met by utility-scale Solar PV systems, again by 2050. That would require an upfront capital cost of 20.5 billion Euros (in 2016€) with a levelized cost of electricity estimated at only €cents 9 per kilowatt-hour. That would lead to roughly 7,500 construction jobs to build capacity, and 11,100 permanent operations jobs to operate and maintain the system in Luxembourg. This highlights an additional advantage of producing renewable energy locally compared to the current situation where Luxembourg imports fossil fuels.

As noted in the Smart Economy portion of the master plan, an increase in product usage means extracting higher value from the resources. This leads to an increase in aggregate efficiency and productivity. A recent assessment by Accenture projected that savings in materials, recycling, and restoration, will likely exceed $4.5 trillion by 2030 in the global economy while increasing productivity, reducing fixed and marginal costs, creating net new jobs, and lowering ecological footprint. An estimated €1 billion of circular economy activities already occur in Luxembourg, employing upwards of 15,000 citizens, mainly in industry, as well as in buildings and construction, and retailing. The potential value in advancing Luxembourg's circularity practices by yet another €1 billion in net-material cost savings per year would generate several thousand more jobs within 36 months. This would require scaling circular activities throughout the automotive, construction, financial, logistics, manufacturing, and RDI sectors.

The drop to near zero GWh of the existing energy resources leads to the positive outcome of zero energy-related carbon emissions by 2050.[391] This result is driven by the scaled-up set of investments in energy efficiency and renewable energy technologies. Looking ahead to Table 7, the overall energy-related annual investments in the TIR Innovation scenario are made up of energy efficiency improvements, on the one hand, and renewable energy options, on the other hand. The volume of these investments is just under 100 million euros in 2017, growing slowly to an estimated 500 million by 2030. From there the investments decline somewhat to 377 million by 2050, with an average annual investment of 420 million in energy-related technologies.[392] The reason for that very small reduction in annual investments in later years is because the less costly energy efficiency improvements begin to pick up more market share and penetration in 2030. This requires, in turn, a smaller contribution from the slightly more-expensive investments in the renewable energy resources—even as those fixed costs also decline as described below.

Over the full period 2017 through 2050, the cumulative mix of annual energy efficiency and renewable energy investments will add up to just over €14 billion (in 2015 constant euros). This is substantially less than the €20.6 billion reflected in the Table 3 thought experiment. Part of the reason is that, according to Fraunhofer's KomMod model, and as reviewed in the paragraph following Table 3, the renewable energy costs are expected to decline over time compared to the example characterized in Table 3. At the same time, however, there will be other information and infrastructure upgrades which might roughly triple the magnitude of investments suggested for the energy-related improvements alone. While the information does not exist in sufficient detail to provide a precise estimate of necessary investments for the non-energy infrastructure improvements, drawing from a variety of sources suggests a cumulative TIR-related investment that is on the order of €46 billion. This is the equivalent of about one year's GDP invested to upgrade the infrastructure, equipment and appliances in Luxembourg over the next several decades. Still, the lack of better data on these related costs, as they might be estimated for the Grand Duchy, is why we continue to emphasize the need for new metrics applicable to the build out of the Third Industrial Revolution digital infrastructure in order to facilitate future assessments.

[391] Although not emphasized as part of this assessment, by focusing on the economic perspective to generate significant cost-effective investments in both energy efficiency and renewable energy technologies, the economy clearly benefits from lower overall costs. At the same time, as that mix of clean energy technologies penetrates the market, the need for fossil-fuel resources slowly (and cost-effectively) declines to zero. This means that the Luxembourg economy will have zero energy-related carbon emissions by 2050. Hence, the more productive pattern of energy efficiency and other clean energy investments produces a significant benefit for global climate change that should exceed the anticipated target of the December 2015 Paris accord.

[392] For added clarity, the energy efficiency improvements average €105 million per year while the renewable energy deployments average €305 million per year.

Also embedded in Table 6 are data that show two key highlights. The first is a small net cost in the initial year of the TIR innovation scenario. Assuming the initiatives begin in the year 2017, initial policy costs and capital outlays create activity for which there are no immediate net savings. Hence, the TIR Innovation Net Energy Savings are a negative €14 million in that year. But the second key highlight reveals a significant reduction in Luxembourg's overall cost of energy services in subsequent years. Rather than a suggested annual cost of €2,190 million in the Reference Case, for example, the TIR Innovation Scenario shows a much smaller energy bill of €1,369 million—an annual savings of €821 million by 2050. There is one minor caution that was previously-discussed and that needs to be raised once again. The €821 million cost reduction represents what might be termed gross energy savings. A more useful metric is the net energy bill savings in that same year. This mirrors the costs of related programs and policies, as well as the amortized payments made for the energy efficiency upgrades which equals €336 million. Therefore, the net savings in 2050 is €485 million. This point is very similar to the discussion surrounding Figure 3 which tracks the range of average annual expenditures over the period 2016 through 2050. In that period, the average annual energy savings of €420 million is actually closer to €250 million when the added program costs together with the amortized energy efficiency upgrades are also included.

At the same time, however, there are large reductions in the cost of externalities highlighted by the Stanford University report, which if included in the assessment here, would further extend the benefits of the TIR Innovation Scenario. In addition, there are the larger productivity returns that come with the evolving interoperability of the Internet of Things TIR infrastructure, as noted by the ACEEE, Cisco, General Electric, McKinsey, and AT Kearney studies. The productivity benefits would also increase the robustness and vigor of the Luxembourg economy. Although these gains are generally referenced among the last four economic drivers identified in Table 1, they are not included in this particular assessment because of the paucity of impact-specific data that are collected and maintained to evaluate these outcomes. This point further underscores the importance of generating new metrics and building new analytical techniques that can enable policy makers and businesses to more effectively evaluate future decision-making as suggested in the discussion that follows.

REVIEWING THE ECONOMIC IMPACTS OF THE TIR INNOVATION SCENARIO

The foundation for the overall economic assessment that has been completed as part of the Luxembourg Third Industrial Revolution master planning process is the proprietary modeling system known as the **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine (DEEPER). The model, developed by John A. "Skip" Laitner, is a compact 15-sector dynamic input-output model of a given regional or national economy.[393] The model is essentially a recipe that shows how different sectors of the economy are expected to buy and sell to each other, and how they might, in turn, be affected by changed investment and spending patterns. Setting up that recipe is a first step in exploring the future job creation opportunities and other macroeconomic impacts as the Luxembourg economy shifts from the Second Industrial Revolution to the higher level of performance that is likely to be associated with the Third Industrial Revolution (TIR).

Although it has only recently been updated to reflect the economic dynamics specific to Luxembourg, the DEEPER model has a 26-year history of development and application. The model has been utilized, for example, to assess the net employment impacts of proposed automobile fuel economy standards within the United States.[394] More often, it is typically employed to evaluate the macroeconomic impacts of a variety of energy efficiency, renewable energy, and climate policies at the regional, state, and national level. As a recent illustration, it was used in 2013 to assess the potential outcomes and economic benefits of the Third Industrial in Nord-Pas de Calais, an industrial region of four million people in northern France.[395]

The timeframe of the model for evaluating energy efficiency and renewable energy technology policies and investments is 1990 through 2050. The period 1990 (or earlier as needed) through 2015 provides a useful historical perspective. The period 2016 through 2050 provides an

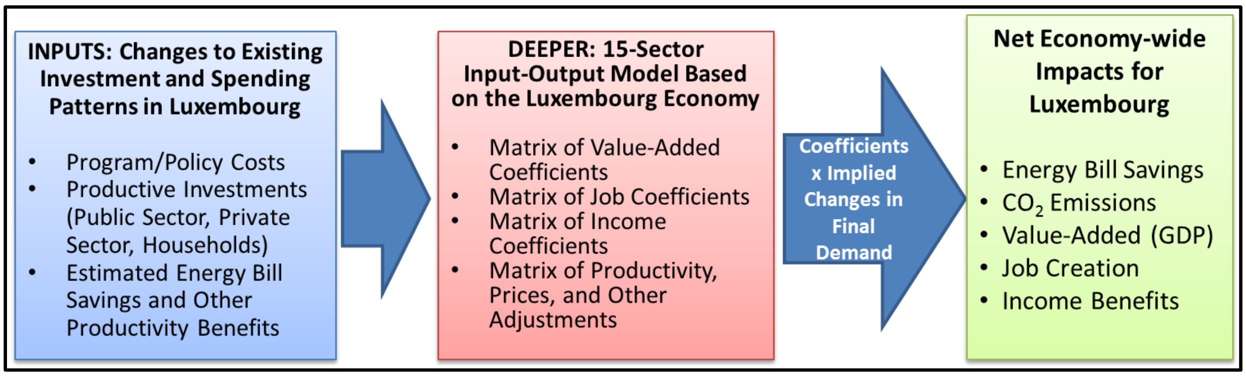
[393] There is nothing particularly special about this number of sectors. The problem is to provide sufficient detail to show key negative and positive impacts while maintaining a model of manageable size. Expanding or reducing the number of sectors will require some minor programming changes and adjustments to handle the larger matrix.

[394] *Gearing Up: Smart Standards Create Good Jobs Building Cleaner Cars*, by Chris Busch, John Laitner, Rob McCulloch, and Ivana Stosic, Washington, DC: BlueGreen Alliance, 2012. Based on this analysis and other evidence, American President Barack Obama signed into effect the proposed 54.5 mile-per-gallon fuel economy standards in August 2012.

[395] Nord-Pas de Calais Third Industrial Revolution Master Plan – 2013, by Jeremy Rifkin, Benoit Prunel, Solenne Bastie, Francis Hinterman, John Laitner and Shawn Moorhead. Bethesda, MD: TIR Consulting Group LLC. 2013. Note that since the release of this master plan, and the development of hundreds of projects based on that plan, Nord-Pas de Calais recently merged with the region of Picardy to form a new region of some 6 million inhabitants now referred to as Hauts-de-France.

assessment of future trends. As it was implemented for this analysis, the model maps the changed spending and investment patterns based on the Third Industrial Revolution Innovation Scenario for the Master Plan over the period 2017 through 2050. It then compares that changed spending pattern to the employment and value-added impacts assumed within the standard reference case. Figure 4, immediately below, provides a diagrammatic view of the DEEPER Modeling System as it was reflected within the dynamics of the Luxembourg economy.

Figure 4. The DEEPER Modeling System



Although DEEPER includes a representation of both energy consumption and production as well energy-related carbon dioxide (CO_2) emissions, the analysis for Luxembourg focused on the changes in larger resource productivity as well as improvements in infrastructure, information and communication technologies, and especially greater circularity within the economy of the Grand Duchy of Luxembourg. These prospective changes in infrastructure and technologies are characterized elsewhere in the Strategy Study. The economic assessment described here is a high level summary of these changes.[396] The model outcomes are driven by the demands for energy services, economic goods and alternative investment patterns as they are shaped by changes in policies and prices. As noted in the previous section, the model built on an assumed reference case over the period 2015 through 2050 as reflected in a variety of data published by the Institut national de la statistique et des études économiques (STATEC), the European Commission, the Organization of Economic Cooperation and Development, and the International Energy Agency, among other organizations and universities.

[396] See, for example, both the assumptions and scenarios described in the section on Energy that follows this Exploration of the Economic Benefits. Of particular note is the data found in Table 2 in the Energy section which informs the set of changes referenced in Table 6 of this section. While Table 6 highlights total energy consumption for the respective scenarios, Table 2 in the Energy Section highlights each of the building, industry, and transportation subtotals which are reflected here.

Trends that Shape the Reference Case

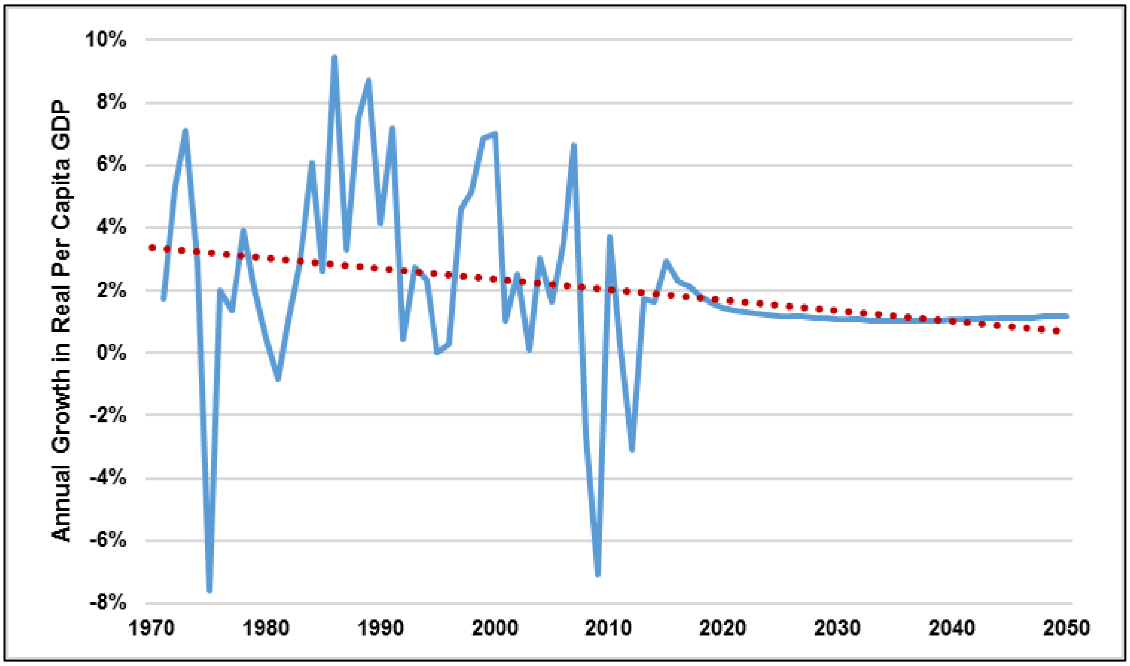
Using a number of these national economic projections, and with preliminary inputs from STATEC, as well as key high-level reference case data, Tables 2 and 6 (shown previously) provide a useful starting point in the assessment through the year 2050. As highlighted in the results reported in Table 7 that follows, we can compare these reference case assumptions with expected results that might emerge from one or more TIR Innovation Scenarios.

There are two key trends that have not been highlighted in the tables above but underscore the emerging positive impact of the TIR Innovation Scenario. The first is the growth in economy-wide productivity as measured by GDP value per job (in million real 2005 Euros). Compared to a historical 1.4 percent annual growth rate over the years 1985 to 2010 (not shown here), recent projections for per capita GDP suggest a growth that is less than half that historical pace. In the 10-year period 2010 to 2020, reflecting the economic volatility of the previous 10-year period, the rate of productivity of the Luxembourg economy is projected to fall to 0.58 percent per year. The good news is that the trend increases slightly to 1.28 percent annually over the 30-year period 2020 through 2050. It is this trend, among other metrics, the prompted the OECD to release its 2015 report on the *Future of Productivity* (see footnote 11 for a further discussion and citation).

At the same time, there is a second trend that hints at a less resilient future economy – in this case because of a declining rate of investment. Recent projections indicate that the rate of Gross Fixed Capital Formation—in effect the growth of annual investments in Luxembourg's total fixed assets—is also decreasing compared to historical performance.[397] Data from the OECD show that over the same 25-year period 1985 to 2010, it averaged 20.4 percent of GDP (not shown here).

[397] Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress."

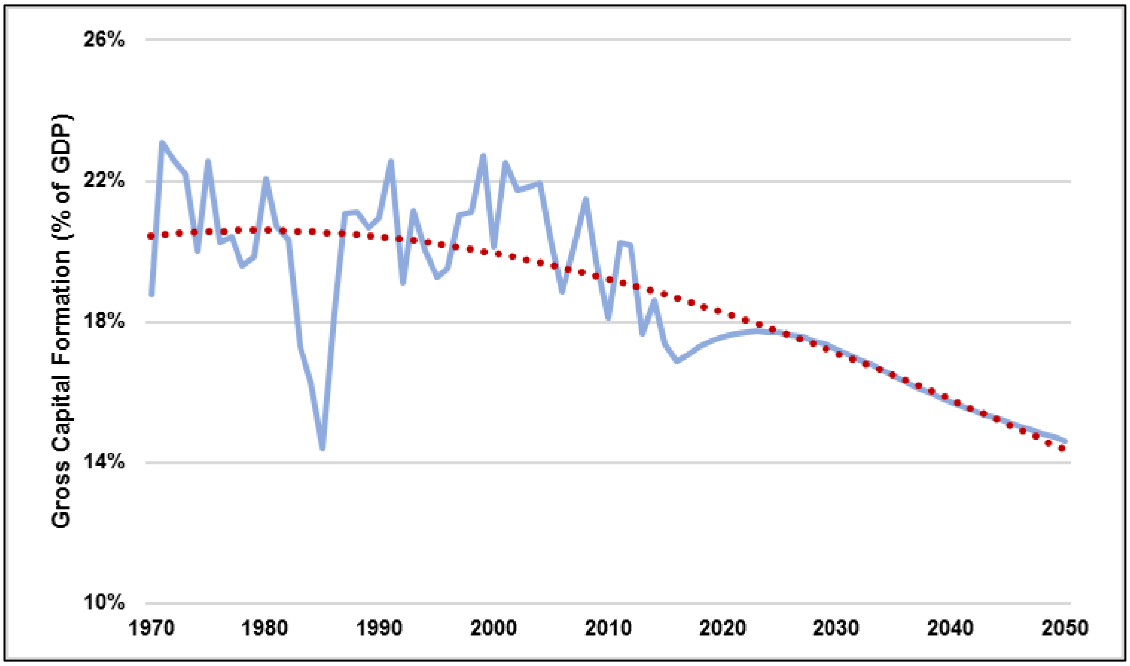
Figure 5. Luxembourg's Growth in Per Capita GDP[398]



Source: OECD Historical and Long-term Baseline Projections (May 2016).

[398] Because Luxembourg has such an open economy, and with roughly 40 percent of jobs held by non-domestic borderers, the metric GDP per job may be the better metric for comparing larger economic productivity than per capita GDP. At the same time, OECD data are not usefully and immediately available for this long-term historical and future comparison. Yet, the larger trends continue to provide critical insights.

Figure 6. Luxembourg's Rate of Gross Capital Formation



Source: OECD Historical and Long-term Baseline Projections (May 2016).

As suggested in the OECD data, the annual rate is projected to actually decrease each year, dropping to a low of 14.6 percent by 2050. Both Figures 5 and 6 above provide a more detailed look at these key trends.

Given this backdrop, as well as the discussion around Figures 5 and 6, an important question to be explored within the Third Industrial Revolution planning process is whether Luxembourg's economy can remain both vigorous and sustainable as per capita GDP and the rate of Gross Capital Formation are shown to possibly decrease. The question that might be helpful to pose is what mix of purposeful effort and more productive investments might ensure the development of a more robust economy. Part of the answer has already been addressed in the discussion surrounding Table 6. But it also lies in the short comment that opened this narrative, and that builds on an extended set of comments about the lagging rate of big energy efficiency and productivity improvements. We will now return to that discussion in greater detail.

Understanding the TIR Innovation Scenario

A working analysis based on data published by the International Energy Agency (IEA) suggests that Luxembourg may convert less than 20 percent of the available energy into useful work.[399] This is a better rate of conversion than for the United States (14.4 percent), OECD nations (16.2 percent) and for the world as a whole (13.5 percent). Yet that still means the Luxembourg economy wastes more than 80 percent of the energy consumed in the economic process. However, the Table 2 data previously referenced suggests that Luxembourg's energy intensity is projected to decline at about 3 percent per year through 2050. This is close to twice Europe's 1.7 percent rate of improvement over the last decade or so.[400] The TIR Innovation Scenario explores the mix of investments that will accelerate the rate of energy efficiency improvements to about 4 percent per year.

The TIR Innovation Scenario also advances the movement toward an energy production system that is anchored by an array of profitable renewable energy technologies.[401] If evaluated properly, a higher level of energy efficiency investments, together with the development of cost-effective renewable energy systems, is likely to result in a downward pressure on the total cost of energy services which, in turn, provides a further net gain for the larger economy.

Table 7 integrates the innovation scenario cost data found in Table 6 and elsewhere. It then lays out the larger economic benefits that might be expected to emerge with the TIR Innovation Scenario, especially as business and policy leaders think through which initiatives most usefully provide the underpinnings of a TIR Master Plan.

[399] Here useful work refers to the consumption of energy as it enables the transformation of materials and other resources into the desired mix of goods and services within the Luxembourg economy.

[400] With the global agreement to contend with climate change now taking effect on 4 November 2016 after support from the European Union, the EU is likely to at least double its rate of energy efficiency improvement closer to where Luxembourg is already going as a reference case. See http://www.reuters.com/article/us-climatechange-paris-idUSKCN12523G.

[401] Given the scant data about the macroeconomic impacts of reducing the cost burden of externalities, as well as the scant data on the prospective benefits of an increased interoperability among Luxembourg sectors and structures, the TIR Innovation Scenario necessarily provides only a working assessment of these benefits.

Table 7. Energy Costs and Impacts from the TIR Innovation Scenario

Economic Impact	Metric	2017	2020	2030	2040	2050	Annual Average 2016-2050
Efficiency Gain	Savings from RefCase	1%	5%	15%	25%	33%	n/a
Policy, Program, Transaction Costs	Million $Euros_{2015}$	8	16	33	24	19	25
Energy-Related Technology Investments	Million $Euros_{2015}$	97	221	500	432	377	420
Net Energy Bill Savings	Million $Euros_{2015}$	-14	52	197	350	485	250
Energy Bill Savings Employment	Net Jobs	1,100	2,500	5,200	4,400	3,700	4,300
Productivity Employment	Net Jobs	200	800	3,200	7,100	13,700	5,300
Other TIR Infrastructure Employment	Net Jobs	1,800	4,700	12,000	16,500	25,100	13,800
Total TIR Innovation Employment Benefits	Net Jobs	3,100	8,000	20,400	28,000	42,500	23,400
Net GDP Impacts	Million Real Euros	100	300	1,000	1,700	2,900	1,300

Source: Output from the DEEPER Modeling Systems as described in text manuscript that follows.

Three things might be noticed immediately in Table 7. First, the very first row of the table stresses the importance of supplemental gains in the overall energy efficiency of the Luxembourg economy. In effect, the total energy demands in an already energy-efficient reference case are cost-effectively reduced by yet another 33 percent in the period 2017 to 2050. Second, there is a coincidence between the rounded average annual energy bill savings of 419.7 million euros and the annual average investments of 421.4 million euros. Both figures are rounded off to €420 million as they are reported in Figure 3, Table 6, and Table 7 above. Finally, although not shown in this table or Table 6, the presumed investment and the more productive TIR build-out of the Luxembourg economy will clearly increase the scale of gross capital fixed formation. Because of the greater level of cost savings, this will stimulate both a more vigorous level of GDP per job as well as a slight increase in the total number of jobs.

The end result of the TIR Innovation Scenario is an economy that, by 2050, expands employment by about five percent more than otherwise anticipated. There is a net gain of energy-driven employment—an annual average of 4,300 net jobs over the 33-year period ending in 2050. In effect, these jobs are made possible by the extensive upgrade of Luxembourg's energy-related infrastructure. Such jobs are further complemented by an additional 5,300 net jobs made possible annually by the non-energy productivity benefits that will be stimulated by an energy-led productivity improvement. Finally, there is a working estimate of about 13,800 average annual net jobs from other TIR Infrastructure investments and transitions, whether in blockchain technologies, transportation/logistics, or greater circularity and waste reduction within the production process. Total national employment, then, is estimated to escalate to just under 24,000 net average jobs per year. If the resulting net gain of 24,000 net jobs seems like an overly small benefit, it is because Luxembourg—despite its open and dynamic economy—is a rather small nation. Another way to look at these job estimates is to imagine what might happen if the leadership of Luxembourg scaled to an equivalent success within the entirety of the European population. In that case, a three percent increase in current employment would imply a net gain of about 5 million jobs within the EU.

Immediate Next Steps

Although Table 7 provides useful insights into the benefits of the TIR-related investment scenario, we have already highlighted three additional elements which should be brought forward into any future discussion of possible outcomes. The initial element is an immediate large-scale investment in cost-effective upgrades of the nation's building stock. The intent here is two-fold. The first is to send a signal about the imperative of a more energy-efficient and a more productive economy. Building upgrades are among the best understood of those near-term opportunities. The review of investment opportunities in the Finance section of the master plan provides a variety of self-funding options for Luxembourg buildings, including both rooftop solar energy and energy efficiency upgrades. See, for example, the background discussion of Table 1 in the Finance section of the master plan which implies a reasonably profitable €5.8 billion investment in the Luxembourg building stock over the next ten years or so.

The immediate lessons and insights from the first wave of infrastructure upgrades will help shape a second wave of activity around developing a more circular economy and a digitally-driven transportation and logistics infrastructure. The second intent of this initiative is to provide the means for collecting project data to underpin a new set of metrics. Both the data and the resulting metrics can guide next steps and aid in the assessment of how such projects might contribute to the larger social, economic, and environmental well-being of Luxembourg—beyond the initial energy-related investments and returns.

It is critical, then, to develop a policy database and new analytical techniques that can inform the nation about the potential for more positive outcomes beyond an energy-led investment strategy. While standard economic models and policy assessment tools have generally been able to track and evaluate many of the Second Industrial Revolution economic trends, they are not equipped to fully explore the potential outcomes of TIR-like innovation scenarios.

The working groups and TIR Consulting Group agreed that it was essential to establish a new set of metrics to allow Luxembourg to begin tracking real-time data at the onset of deployment of the Third Industrial Revolution infrastructure. The data would provide the necessary information for documenting immediate project returns and for assessing future aggregate efficiencies, productivity gains, reductions in material and carbon footprints and marginal costs brought on by the interconnectivity of the digital platform.[402] These metrics are in addition to documenting the more traditional metrics, including reductions in energy consumption and greenhouse gas emissions as well as positive changes in jobs, investments, total factor productivity and GDP. As Luxembourg tracks this data in real-time, it will be able to make critical projections on future social, economic and environmental well-being, based on the experience and insights gained at each step of the deployment. A particular focus might be documenting the full costs and benefits of an interoperational digital infrastructure.

When businesses can plug into an increasingly matured digital infrastructure comprised of the digitalized Communication Internet, digitalized Renewable Energy Internet, and digitalized Transportation and Logistics Internet, atop an Internet of Things platform, they will be able to develop and use near-zero marginal cost renewable energy in every single conversion at each stage of their value chains. This will facilitate the smart managing, powering, and moving of economic activity. The leap in aggregate efficiency and productivity, and reduction in material and carbon footprints and marginal cost brought on by the increasing integration and interoperability of the digital Third Industrial Revolution infrastructure, marks both a qualitative and quantitative leap in the economic performance of industries across Luxembourg.

The active tracking of Third Industrial Revolution metrics – again, including aggregate efficiency, productivity, reductions in material and carbon footprints, and marginal cost – will enable the Grand Duchy of Luxembourg to make appropriate adjustments so that the goals are more likely achieved over the successive years. The value of this second step can be seen by again reviewing the macroeconomic returns highlighted in Table 7. The benefits are clearly positive but they yield on only a first indication of the larger potential gains that might accrue to Luxembourg. Among prospective changes that are not fully captured in this assessment are the very real emergence of new markets catalyzed by new fintech models, new digital technologies, new smart industries, and greater circularity.[403] Other effects include the buildup of greater local capacity to supply more of Luxembourg's goods and services. A more informative assessment can be provided by continually updating the collected Big Data as the Third

[402] The current national accounts for Luxembourg now enable the development of what is called here the "material and carbon footprints." At the same time, however, as new metrics are developed, and with new data that can be tracked and maintained, a complementary "ecological footprint" can be eventually developed to fit within what economists call factor production or economic analysis. This may become a useful metric to better document the full range of social, economic, and environmental outcomes that are made possible by different TIR Innovation Scenarios.

[403] The reader is encouraged to review the appropriate sections of the master plan to better understand how these new industries and new markets are likely to drive major changes in the structure and the productivity of the Luxembourg economy.

Industrial Revolution infrastructure is deployed and made increasingly interoperable in subsequent years.

A SHORT NARRATIVE ON THE DEEPER MODELING SYSTEM AS A POLICY ASSESSMENT TOOL

Although the DEEPER Model is not a general equilibrium model as the LuxGEM model now being developed by STATEC, it does provide sufficient accounting detail to match import-adjusted changes in investments and expenditures within one sector of the economy and balance them against changes in other sectors.[404] More to the point of this exercise, it can specifically explore the energy and related non-energy productivity benefits from what is now characterized as a TIR Innovation Scenario—especially as it is transformed into a pro-active Third Industrial Revolution Master Plan.

One critical assumption that underpins the core result of the DEEPER analysis is that *any productive investment or spending—whether in energy efficiency, renewable energy, and/or a more dynamic infrastructure that pays for itself over a reasonably short period of time—will generate a net reduction in the cost of energy services (as well as a lower cost of other resources which are needed to maintain the material well-being of the Luxembourg economy). That net reduction of energy and resource expenditures can then be spent for the purchase of other goods and services.* In other words, as we noted in the discussion surrounding Figure 1, the redirecting of €1 million in value-added spending away from energy suggests there may be roughly a net gain of about 5.8 jobs. Depending on the many sectoral interactions, as well as the complete assessment of the many effects summarized and discussed in Table 1 of this assessment, the net gain in jobs may widen or close as the changed pattern of spending works its way through the model, and as changes in labor productivity changes the number of jobs needed in each sector over a period of time.[405]

[404] When both equilibrium and dynamic input-output models use the same technology, investment, and cost assumptions, both sets of models should generate reasonably comparable set of outcomes. For a diagnostic assessment of this conclusion, see, “Tripling the Nation’s Clean Energy Technologies: A Case Study in Evaluating the Performance of Energy Policy Models,” Donald A. Hanson and John A. “Skip” Laitner, *Proceedings of the 2005 ACEEE Summer Study on Energy Efficiency in Industry*, American Council for an Energy Efficient Economy, Washington, DC, July 2005.

[405] Note that unlike many policy models, DEEPER also captures trends in labor productivity. That means the number of jobs needed per million dollars of revenue will decline over time. For example, if we assume a 1.5 percent labor productivity improvement over the 36-year period from 2014 through 2050, 16 jobs supported by

Once the mix of positive and negative changes in spending and investments has been established for the Third Industrial Revolution Innovation Scenarios, the net spending changes in each year of the model are converted into sector-specific changes in final demand. Then, following the pattern highlighted in the diagram of the DEEPER Modeling System, the full array of changes will drive a dynamic input-output analysis according to the following predictive model:

$X = (I-A)^{-1} * Y$

where:

X = total industry output by a given sector of the economy

I = an identity matrix consisting of a series of 0's and 1's in a row and column format for each sector (with the 1's organized along the diagonal of the matrix)

A = the matrix of production coefficients for each row and column within the matrix (in effect, how each column buys products from other sectors and how each row sells products to all other sectors)

Y = final demand, which is a column of net changes in spending by each sector as that spending pattern is affected by the policy case assumptions (changes in energy prices, energy consumption, investments, etc.)

This set of relationships can also be interpreted as

$\Delta X = (I-A)^{-1} * \Delta Y$.

This reads, a change in total sector output equals the expression $(I-A)^{-1}$ times a change in final demand for each sector.[406] Employment quantities are adjusted annually according to exogenous assumptions about labor productivity. From a more operational standpoint, the macroeconomic module of the DEEPER Model traces how each set of changes in spending will work or ripple its way through the regional economy in each year of the assessment period. The end result is a net change in jobs, income, and GDP (or value-added).

For a review of how an Input--Output framework might be integrated into other kinds of modeling activities, see Hanson and Laitner (2009). While the DEEPER Model is not an

spending of 1 million Euros today may support only 9.4 jobs by the year 2050. The calculation is $16 / 1.015^{(2050-2014)}$ = 9.4 jobs (in rounded terms).

[406] Perhaps one way to understand the notation $(I-A)^{-1}$ is to think of this as the positive or negative impact multiplier depending on whether the change in spending is positive or negative for a given sector within a given year.

equilibrium model, as explained previously, we borrow some key concepts of mapping technology representation for DEEPER, and use the general scheme outlined in Hanson and Laitner (2009).[407] Among other things, this includes an economic accounting to ensure resources are sufficiently available to meet the expected consumer and other final demands reflected in different policy scenarios.

[407] "Input-Output Equations Embedded within Climate and Energy Policy Analysis Models," by Donald A. Hanson and John A. "Skip" Laitner, in Sangwon Suh, Editor, *Input-Output Economics for Industrial Ecology*. Dordrecht, Netherlands: Springer, 2009. See also, "A Pragmatic CGE Model for Assessing the Influence of Model Structure and Assumptions in Climate Change Policy Analysis," by Stephen Bernow, Alexandr Rudkevich, Michael Ruth, and Irene Peters. Boston, MA: Tellus Institute, 1998.

TIR Consulting Group LLC Biographies

In Alphabetical Order

Frits BLIEK

Frits Bliek is a Principal Consultant for DNV GL, with over 10 years experience in the energy sector, preferentially active in transition projects in the area of strategy, business analysis and innovation in the energy market. His analytical skills combined with his in-depth knowledge of the energy business, processes and systems allow him to develop detailed models and perform thorough analyses. His power lies in his enthusiasm and focus on results that matter. In this way he is capable of leading multi-disciplinary highly educated teams, such as the USEF design team, in an inspiring way and delivers innovative results of high quality. Timely identification of the essential business risks and providing to-the-point insight into these risks as well as the consequences and solutions make him a valued adviser on the board level.

John BYRNE

John Byrne is the Chairman and President of the Foundation for Renewable Energy & Environment (FREE). The Foundation was created in 2011 with a mission of promoting a better future based on energy, water and materials conservation, renewable energy use, environmental resilience, and sustainable livelihoods. Dr. Byrne has contributed since 1992 to Working Group III of the Intergovernmental Panel on Climate Change (IPCC). His work is published in IPCC assessments which led to greater global awareness of the problem and the award of the 2007 Nobel Peace Prize to the Panel.

He is the architect of the Sustainable Energy Utility (SEU) model and its innovative energy efficiency finance program, which received U.S. White House recognition as part of the nation's Better Buildings Challenge. The Asian Development Bank has also recommended the model to its member countries.

From 2007 to 2012, he co-chaired the Delaware Sustainable Energy Utility Oversight Board. Delaware was the first jurisdiction to create an SEU modeled on Dr. Byrne's work. He presently leads FREE's efforts to diffuse this model, with initiatives in Pennsylvania (the Pennsylvania Sustainable Energy Finance Program or PennSEF – a partnership with Pennsylvania Treasury, Drinker, Biddle, Becker Capital, and West Penn Power Sustainable Energy Fund), California (the Sonoma County Efficiency Finance Program or SCEF), South Korea (the Seoul Metropolitan Government recently signed an MOU with FREE), and others.

In addition to his role at FREE, Dr. Byrne is Distinguished Professor of Energy and Climate Policy and Director of the Center for Energy and Environmental Policy (CEEP) at the University of Delaware. CEEP's graduate program is ranked among the three best in the field. As well, he holds an appointment as Distinguished Professor of Sustainable Energy at the Daegu Gyeongbuk Institute of Science and Technology, a new university created by South Korea to lead its plan for green energy technology and policy development.

Dr. Byrne is a founding member of and serves on the board the International Solar Cities Initiative – a pioneering program to assist cities around the world in building sustainable futures. He has served on the National Council for Science and the Environment (U.S.) and advised the Interagency Working Group on Environmental Justice, coordinated by the U.S. EPA. He received a Fulbright Senior Lecturer/ Researcher Award to teach environmental policy at the Graduate School of Environmental Studies, Seoul National University, and to conduct research on a National Greenhouse Gas Abatement Strategy for the Korea Energy Economics Institute. Dr. Byrne has been recognized by the Chinese government for his expertise in energy and environmental policy and his name appears on China's foreign expert registry. He is an advisor to the Chinese Academy of Sciences and also the Chinese Academy of Social Sciences, The Energy and Resources Institute (TERI in India) and the Korea Energy Economics Institute, among others. His work has been funded by the World Bank, UNEP, the Blue Moon Fund, the Chinese Academy of Science, the Energy Research Institute of China's National Development and Reform Commission, the Korea Energy Economics Institute, the Korea Institute of Science & Technology, the Green Technology Center–Korea, The Energy Research Institute (TERI, New Delhi, India), the National Science Foundation, U.S. Department of Energy, the National Renewable Energy Laboratory, and the U.S. EPA, among others. He has published 17 books and over 160 research articles.

Michael CASEY

Michael Casey is, among other roles, a senior advisor for blockchain opportunities at the MIT Media Lab's Digital Currency Initiative and an advisor to the Agentic Group. At MIT, he is seeking to build awareness around digital currencies and the underlying blockchain technology, helping to shape scholarship around the topic and exploring dedicated research projects that use this emerging technology to achieve social impact goals. At Agentic, he is engaged in real-world, early-stage deployments of that technology.

Before joining MIT in 2015, Michael was a senior columnist covering global finance at The Wall Street Journal. In a career spanning five continents, he covered currencies, bonds, equities and economic policy for The Journal, Dow Jones Newswires and various other media outlets. He also did a great deal of TV and radio work, hosting TV shows produced by the WSJ Live team and appearing on numerous networks as a commentator, including CNBC, CNN, Fox Business and the BBC.

After taking an interest in bitcoin and digital currencies in 2013, Michael and colleague Paul Vigna founded the Bitbeat column, a regular survey of developments in the field that's published on WSJ's Moneybeat blog. The pair went on to co-author the critically acclaimed book, The Age of Cryptocurrency: How Bitcoin and Digital Money are Challenging the Global Economic Order and have collaborated with documentary film makers on the topic. Michael is now a frequent public speaker, where he speaks about digital currency themes and applications for the blockchain ledger. He also advises institutions on how to understand the challenges and opportunities that are emerging from this disruptive, decentralizing technology.

Before the Age of Cryptocurrency, Michael had written two prior books: *The Unfair Trade: How our Broken Global Financial System Destroys the Middle Class*, an analysis the global dimensions of the recent financial crisis, and *Che's Afterlife: The Legacy of an Image*, about the famous photo of Ernesto "Che" Guevara by Alberto Korda.

A native of Perth, Australia, Michael is a graduate of the University of Western in Australia. He also has higher degrees from Cornell University and Curtin University.

Elisabetta CHERCHI

Currently working as an Associate Professor at the Department of Transport, Technical University of Denmark, and has a joint appointent with the University of Cagliari in Italy.

Her main research interests are in the area of modelling consumer behaviour, microeconomic derivation of behavioural models, data collection, demand model estimation and preditiction and user benefit evaluation. Her major interest is in understanding what drives sustainable transport behaviour (i.e. shift toward public transport, electric vehicles, driverless vehicles and bicycles) and how it can be promoted.

She has published 45 papers in peer-reviewed international journals (such as *Transportation Research Part A, B, D, F; Transportation; Transportation Science; Transport Policy*) and book chapters and presented more than 70 papers at international congresses. She is currently Area Editor of the journal *Transportation,* member of the Editorial Boards of three other prestigious transport journals: *Transportation Research part B*, *Journal of Choice Modelling* and *Transport Policy*. She has been invited to give seminars at top world universities (such as EPFL, Northwestern, Maryland, Pontificia Universidad Católica de Chile, Imperial College, ETH Zurich) and workshops on the future direction of the research at three of the most relevant conferences in the field: IATBR 2009 and 2015, ISCTSC 2014 and TRB 2012.

She is currently Vice-Chair of the *International Association for Travel Behaviour Research* (IATBR) where she also served for four years as Secretary and Treasurer. She has also been a member of the Ph.D. evaluation committees of 9 students and served as member of the evaluation committee to appoint an Assistant Professor and an Associate Professor in Sweden and as referee for National funds to university research in Switzerland, the Netherlands, and in Chile.

During her career she has also had a leading role in many national and international research projects, such as the Green eMotion project, a major project with more than 40 partners, funded by the European Commission, the 7th Framework program, where she was responsible to study consumers' preferences and attitudes to electric vehicles; the economic evaluation of projects for the regeneration of urban sites of environmental interest, funded by Italian Ministry for University Research; and the GREAT project (Green Regions with Alternative Fuels for Transport), another research project funded by the European Commission where she is currently responsible for studying the effect of dissemination/communication and awareness on the use of a new network of recharging points for alternative fuel vehicles. She has also collaborated on several international projects funded by the by the Spanish Ministry for University Research, the Department for Transport in UK; the Ministry of Transport, Spanish Government. She is also currently a member of the Board of Directors of the Airport of Cagliari, Italy (around 4 million passengers/year).

Daniel CHRISTENSEN

Daniel currently serves as Chief of Staff at TIR Consulting Group LLC. Prior to joining TIR Consulting Group LLC, he gained valuable professional experience at the European Parliament in Brussels, Belgium, and the Assembly of European Regions in Strasbourg, France.

He holds a Master of Arts in International Relations and Diplomacy Studies of the European Union from the College of Europe in Bruges, Belgium and a Bachelor of Arts in International Relations from Claremont McKenna College in California, United States.

His MA dissertation is entitled "The European Parlaiment as an International Actor after Lisbon: A Case Study in Washington D.C.," and his BA dissertation is entitled "The 'Grand Bargain' of the 21st Century: Assessing the Adequacies and Inadequacies of the Liberal Intergovernmental Theory of European Integration in Explaining the Treaty of Lisbon."

Giovanni CORAZZA

Giovanni Emanuele Corazza, PhD, is a Full Professor in Telecommunications at the Alma Mater Studiorum University of Bologna, the oldest academic institution of the Western World. Since 2012, he has been a Member of the University of Bologna Board of Directors, the highest governance body in the institution. He was Head of the Department of Electronics, Computer Science and Systems (DEIS) from 2009-2012 and Chairman of the School for Telecommunications from 2000-2003. He is the President of the Scientific Council of the Fondazione Guglielmo Marconi, and a Member of the Marconi Society Board of Directors. Giovanni E. Corazza is the founder of the Marconi Institute for Creativity, a body created as a joint initiative of the Fondazione Guglielmo Marconi and the University of Bologna, to investigate and divulgate all of the most research scientific evidence on the creative thinking process in humans and in artificially intelligent machines. Since 2014 he has been Vice-Chairman of NetWorld2020, the European Technology Platform dedicated to the future evolution of communication networks, and Member of the Board of the 5G Infrastructure Association, the private side of the 5G-PPP with the European Commission. Giovanni E. Corazza was the Chairman of the Advanced Satellite Mobile Systems Task Force (ASMS TF), and Founder and Chairman of the Integral Satcom Initiative (ISI), a European Technology Platform devoted to Satellite Communications. He was a co-founder of Mavigex S.r.l., a spin-off company dedicated to the development of innovative smartphone applications. During his career he also worked for Qualcomm (California, USA) and COM DEV (Ontario, Canada). He has been the principal investigator in more than 20 European projects funded by the European Commission and by the European Space Agency. He is a Member of the Editorial Board of the Journal of Eminence and Genius. From 1997-2012, he has served as Editor for Communication Theory and Spread Spectrum for the IEEE Transactions on Communications. He is the author of two books and of more than 300 papers on diversified topics in wireless and satellite communications, mobile radio channel characterization, Internet of Things, navigation and positioning, estimation and synchronization, spread spectrum and multi-carrier transmission, scientific creative thinking. Giovanni E. Corazza received the Marconi International Fellowship Young Scientist Award in 1995, the IEEE 2009 Satellite Communications Distinguished Service Award, the 2013 Newcom# Best Paper Award, the 2002 IEEE VTS Best System Paper Award, the Best Paper Award at IEEE ISSSTA'98, at IEEE ICT2001, and at ISWCS 2005. He has been the General Chairman of the IEEE ISSSTA 2008, ASMS 2004-2012 Conferences, and of the MIC Conference 2013. He has taught several graduate and undergraduate courses on Digital Transmission, Mobile Radio Communications, Principles of Multimedia Applications and Services, Software for Telecommunications, Information Theory and Coding, Digital Receiver Design and Optimization, Creativity and Innovation. He is a Member of the Scientific Committee of the Bologna Business

School, where he contributes also to the Executive Master in Technology and Innovation Management.

Kathleen GAFFNEY

Kathleen Gaffney is a Managing Director in Navigant's Global Energy practice, based in London. With more than two decades of experience in managing large-scale, multi-year engagements and overseeing the work of large interdisciplinary research teams, Kathleen plays an integral role in advising energy clients on demand-side policies, markets, and programmes. Her work centres on directing targeted market research that incorporates robust data analytics, customer segmentation, and behaviour modelling to help clients better understand evolving customer expectations and strengthen their competitive position in a rapidly changing environment. Kathleen has completed hundreds of impact assessments, process evaluations and technical research studies across a wide range of energy sector initiatives including those targeting residential, commercial, institutional and industrial sectors.

Prior to joining Navigant, Kathleen was based in London and responsible for leading DNV GL's European-focused practice on energy and climate policy and programme evaluation and, during 2013-2014, she fulfilled a similar assignment based in Sydney, Australia. Prior to 2013, Kathleen co-led a US-based evaluation practice totalling US$ 30+ million in annual revenues. Kathleen's team focused nearly exclusively on energy policy and programme evaluation for a range of government and energy sector clients. Kathleen has more than 20 years' experience in the evaluation field and has supported skills and expertise development for more than 150 energy and climate policy and programme evaluation practitioners worldwide.

Kathleen holds a BS in Economics and International Relations from The American University, Washington, DC, and an MA in Energy Management and Policy / Appropriate Technology from the University of Pennsylvania, Philadelphia, PA.

Rob van GERWEN

Rob van Gerwen is a very experienced senior technical consultant at DNV GL with a background in physics. He managed and supported many projects in the field of domestic, utility and industrial energy use. His current field of activity is smart meters and smart grids. He was involved in many (international) smart meter or smart grid projects, including smart meter cost benefit analyses for the Netherlands, Turkey, Cyprus, Belgium, Portugal and Australia. He managed and contributed to many technical due diligence and technical review projects. He developed several methodologies for assessing renewable energy projects, energy efficiency projects and smart metering/smart grid projects, both technically and financially. He worked as a smart grid/demand response expert in a large international project for a meter manufacturer. He has additional technical experience with decentralized energy conversion technologies (micro-CHP, fuel cells, ORC-units) and is asked to perform technical due diligences in this area on a regular basis.

Luca GUALA

Luca is founder partner of MLab srl, a consulting company started in 2012 in Cagliari, Italy, which specializes in transport solutions and planning consultancy with a strong focus on sustainability and innovation. Currently, his current position within MLab is technical director. In 2015 and 2016 he taught noise assessment techniques in professional training courses.

In 2013 he worked as Chief Engineer with responsibility in Transport for the Perm City Project Bureau (Perm, Russia). From 2005 to 2011 he worked as specialist consultant first, then project director, for the transport planning Company Systematica, Milan, Italy, focusing his activity on innovative and sustainable transport solutions, urban transport plans, transport consultancy to urban planners and master-planning. Previously, he worked as a researcher at the University of Cagliari, Department of Territory and as free-lance consultant for the transport of waste and of dangerous goods and the assessment of noise and vibrations;

Luca achieved a 5 years degree (MScEng) in transport engineering at the University of Cagliari, Italy, and a PhD in transport technique and economics at the University of Palermo, Italy.

Among Luca's most relevant professional experiences of the last 10 years in the fields of urban scale transport planning, sustainable and innovative transport systems are: 2016: transport plan for the City Stretegic Master Plan of Ekaterinburg, Russia (with MLA+ NL); 2015: strategic transport plan of the city of Ufa, Republic of Bashkortostan, Russian Federation (with UrbanBairam, Ufa); 2013-2014: Transport strategy for the masterplan of a large mixed-use development in Khimki, territory of Moscow, Russia (with Systematica, Italy, KCAP, NL); 2012-2016: design and implementation of the first demonstrator of the "City Mobil 2" E.C. FP7 project to test automated transit systems in a real urban environment (with CTL, University of Rome La Sapienza, Italy); 2013: planning of the automated public transport system for the women's campus of King Abdullaziz University, Jeddah, Saudi Arabia (with 2getthere, NL); 2011-12: "Green eMotion" E. C. FP7 project for sustainable micro-mobility in Rome, Italy (with CTL, University of Rome la Sapienza, Italy); 2010: mobility strategy of the Strategic Master Plan of Brussels Capital Region, Belgium (with KCAP, NL); 2009-2010: mobility strategy for the Strategic

Master-Plan and the General-Plan of the city of Perm', Russia (with CPB Perm, Russia); 2007-2009: innovative, zero-carbon mobility strategy for the Masdar City Masterplan; planning of the autonomous transport system and design of the network for the "MIST Campus" at Masdar City, UAE (with ADFEC, UAE; Fosters & Partners, UK); 2006: public transport, cycling and walking strategies of the Urban Mobility Plan of Cagliari, Italy; with Municipality of Cagliari, Italy

Hans de HEER

Hans de Heer is an experienced project manager at DNV GL, mainly in the field of business process (re)design, system development and implementation in the utilities sector. Focusing on business objectives and processes and based on his extensive technical experience, he excels at translating business needs into information architecture systems.

Over the past several years, Hans has developed specific expertise and experience in Automated Meter Reading (AMR) and Advanced Metering Infrastructure (AMI); allocation, nomination and reconciliation processes, portfolio management, trade and supply, electric mobility and demand side management. Hans is a pragmatic, result driven and committed professional who easily takes responsibility. He is able to think and act on a technical, conceptual or organizational level. Hans is particularly valued when creating order and overview. In this role he consolidates the available information, defines possible actions and supervises the necessary actions leading to implementation.

Philipp KRÜGER

Philipp S. Krüger is Advisor for Cybersecurity at German Fraunhofer SIT and Co-Founder and Member of the Board at American Software Firm Scrapp Inc. Previously he was Director of the Digital Economy Project at Stiftung Neue Verantwortung in Berlin where he advised public and private stakeholders on the implementation of the new "Digital Agenda" policy initiative for Europe. Before that, Philipp advised the Free State of Saxony and the Free State of Bavaria on the creation of regional technology growth investment funds. He was the Co-founder and CEO of Explorist Inc., a U.S.-German Big Data firm which he developed while at M.I.T. Media Lab. Before that, he served as COO of Kirkwood & Sons Technology Investment, a $700mm private equity firm, and worked as project manager at Bertelsmann and Siemens. Philipp currently holds appointments at the Tönissteiner Kreis, the Stifterverband für die Deutsche Wissenschaft, the American Council on Germany, the Milken Institute's Young Leaders Council and the German Center for Research and Innovation. Prior to his work in technology, Philipp served the

United Nations Department of Peacekeeping Operations as Field Officer during the wars in Sierra Leone and Kosovo. Philipp is a graduate of Harvard's Kennedy School of Government, M.I.T Media Lab and Augsburg-University's Law Faculty. Philipp grew up in Munich, Bavaria.

John "Skip" LAITNER

John A. "Skip" Laitner is a resource economist who leads a team of consultants, the Economic and Human Dimensions Research Associates, based in Tucson, Arizona. He also serves as the chief economist for Jeremy Rifkin's Third Industrial Revolution initiatives as well as a senior economist for the Russian Presidential Academy of National Economy and Public Administration (RANEPA). He previously worked almost 10 years as a Senior Economist for Technology Policy with the US Environmental Protection Agency (EPA). He left the federal service in June 2006 to focus his research on developing a more robust technology and behavioral characterization of energy efficiency resources for use in energy and climate policy analyses and within economic policy models.

In 1998 Skip was awarded EPA's Gold Medal for his work with a team of economists to evaluate the impact of different strategies that might assist in the implementation of smart and more productive climate policies. In 2003 the US Combined Heat and Power Association gave him an award to acknowledge his contributions to the policy development of that industry. In 2004 his paper, "How Far Energy Efficiency?" catalyzed new research into the proper characterization of efficiency as a long-term economic development resource. Author of more than 320 reports, journal articles, and book chapters, Skip has 45 years of involvement in the environmental, energy and economic policy arenas.

His expertise includes benefit-cost assessments, behavioral assessments, resource costs and constraints, and the net employment and macroeconomic impacts of energy and climate policy scenarios. His most immediate research focuses on two areas. The first area builds on the work of Robert U. Ayres and examines the links between energy inefficiency and a productive economy. In a book chapter published in 2014, Skip provides a time series dataset that suggests the United States may be only 14 percent energy-efficient, and that it is this level of inefficiency which may constrain the future development of a more robust economy. The second area explores the ways that nations, communities and the energy industry can maximize the economic opportunity of productivity-led investments while minimizing the risk of rising energy prices and disruptive energy supplies.

Claude LENGLET

Claude graduated as engineer from Ecole Centrale de Paris and then obtained a Master's Degree of the University of Colorado (Boulder) in 1971. He started working in prestressed concrete bridge design in a large construction company in Paris, and then moved back to the North of France where he worked in a construction design office from 1981 to 1989, working on wood construction and on new computer aided design tools.

In 1989 he decided to join an Architect team and developed his knowledge of urban planning and architectural design through numerous projects.

In 1998 he became Technical Director for Norpac (a branch office of Bouygues), leading a team of more than fifty engineers and draftsmen. From 2006 to 2009 he was responsible for R & D activities of Bouygues Construction in relation with the European Construction Technology Platform (ECTP). He then took the co-leadership of the E2B European program on buildings energy efficiency, a program that was funded at the level of one billion euros on ten years by the EC.

Starting 2009, he worked as Scientific Director of the Rabot-Dutilleul construction group. He also worked with the World Forum Lille, co-managing a think tank on CSR.

In 2013, for the Regional Chamber of Commerce and Industry and for the Regional Council in Nord-Pas de Calais, he conducted the team and the eight working groups in charge of building up the Third Industrial Revolution Master Plan as a direct interlocutor of Jeremy Rifkin's teams. The Master Plan was successfully presented in October 2013.

Zachary NAVARRO

Zachary Navarro currently holds the position of Program Manager / Executive Assistant for the TIR Consulting Group LLC. Prior to joining the TIR Consulting Group, Zachary's work focused on the development of legislation as he held various positions in the public and private sectors working as a Researcher for the House of Commons of the United Kingdom in London, a Legislative Aide for the United States House of Representatives in Washington DC, and as a Researcher for a management consulting firm on a contract with the Executive Branch of the United States Federal Government.

Zachary holds a Master of Science from the London School of Economics and Political Science where he studied the Politics and Government of the European Union, specializing in informal governance and the foreign policy of the EU. His MSc dissertation was entitled "Foreign Policy

Convergence: The myth of the insurmountable divide between the European Union and the United States". He also holds a Bachelor of Arts from Boston's Northeastern University where he studied Political Science and International Affairs.

Jeremy RIFKIN

Jeremy Rifkin is an American economic and social theorist, author, and advisor to heads of state around the world. Mr. Rifkin is ranked 123 in the WorldPost / HuffingtonPost 2015 global survey of "The World's Most Influential Voices." Mr. Rifkin is also listed among the top 10 most influential economic thinkers in the survey.

Mr. Rifkin is the author of 20 books about the impact of scientific and technological changes on the economy, the workforce, society, and the environment that have been translated into over 35 languages.

Mr. Rifkin has been an advisor to the European Union since 2000. He has advised the past three presidents of the European Commission and their leadership teams – President Romano Prodi, President Jose-Manuel Barroso, and the current President Jean-Claude Juncker. Rifkin has also served as an advisor to the leadership of the European Parliament and numerous heads of state, including Chancellor Angela Merkel of Germany, President Nicolas Sarkozy of France, Prime Minister Jose Luis Rodriguez Zapatero of Spain.

Mr. Rifkin is currently advising both the leadership of the European Union and the People's Republic of China. His book, The Third Industrial Revolution, has become their blueprint for addressing climate change and creating a smart, sustainable, digital global economy. Mr. Rifkin is a principal architect of the European Union's Third Industrial Revolution economic development plan to transform the world's largest economy into a post-carbon smart digital society. Mr. Rifkin's Third Industrial Revolution vision has also been adopted by the People's Republic of China as a centerpiece of its long-term economic development strategy.

Mr. Rifkin is the President of the TIR Consulting Group, LLC comprising many of the leading renewable energy companies, electricity transmission companies, construction companies, architectural firms, IT and electronics companies, and transport and logistics companies. His global economic development team is working with cities, regions, and national governments to develop the Internet of Things (IoT) infrastructure for a Collaborative Commons and a Third Industrial Revolution. The TIR Consulting Group LLC is currently working with the regions of Hauts-de-France (the third largest region in France), the twenty-three municipalities of the Metropolitan Region of Rotterdam and The Hague, and the Grand Duchy of Luxembourg in the conceptualization, build out, and scale up of a smart Third Industrial Revolution infrastructure to transform their economies.

Since 1994, Mr. Rifkin has been a senior lecturer at the Wharton School's Executive Education Program at the University of Pennsylvania, where he instructs CEOs and senior management on transitioning their business operations into sustainable economies.

Francesco SECHI

Francesco graduated in transport engineering at the University of Cagliari; since 1997 he has been working in the field of Transport Planning, taking part to several projects concerning private and public transport issues at national, regional, provincial and urban scale with the role of Planner, Project Manager or Scientific Supervisor.

Mainly the projects were related to the evaluation of major infrastructure projects, such as highways, underground metro, light-rail and tramway, mobility plans, traffic impact assessment, forecast of passenger and freight demand, innovative transport systems. These studies were mainly supported by predictive simulations through the use of transport simulation models. He also acquired a thorough understanding of economic and financial assessment of transport system interventions funded by the European community.

From 2002 to 2011, he has been consultant of Systematica spa firm where he has directed and coordinated the team of the local headquarters of Cagliari (with a workforce of up to 15 engineers). In 2002 he co-founded the local office in Cagliari of Systematica, of which he is a partner since 2005.

In 2012 he co-founded the company "Systematica Mobility Thinklab srl" ("Mlab" in short), an engineering firm based in Cagliari, specialized in planning and feasibility studies of transport systems, addressing both traditional and innovative systems. Currently he is chairman of the board of directors of Mlab.

He is also collaborating with the chair of "transport planning" of the faculty of engineering and with the course of "project management" of the faculty of economics of the University of Cagliari.

Gerhard STRYI-HIPP

Gerhard Stryi-Hipp, head of energy policy and coordinator "Smart Energy Cities" at Fraunhofer ISE, is a physicist and an interdisciplinary expert on technologies, market development and policies in renewable energies and sustainable energy systems. From 1994 to 2008, he was managing director of the German Solar Industry Association BSWSolar and its predecessors. He worked on market support policy for solar thermal and solar photovoltaic in Germany and Europe, on awareness campaigns, on quality assurance measures and technical innovations of the sector. He advocates for intensified research on renewable heating and cooling and in 2005 was one of the initiators of the German and European Solar Thermal Technology Platforms. Since its foundation in 2008, he has been president of the European Technology Platform on Renewable Heating and Cooling, which developed a vision, a research agenda and a roadmap for the sector. In 2009, Gerhard moved to Fraunhofer ISE, the largest solar research institute in Europe. He conducted projects on solar thermal energy systems, e.g. on Solar-Active-Houses which are heated by more than 50% by solar thermal energy. Since 2012 he has focused his work on sustainable energy systems especially for cities and communities. He is an energy expert in the multi-disciplinary Fraunhofer project "Morgenstadt: City Insights". With his research group "Districts and Cities" he is developing modelling tools to identify and design cost-effective sustainable energy systems for cities and regions. Based on these scenarios backwarding methods are used to derive roadmaps for the transformation of urban energy systems towards sustainability. Since 2014, he has been a member of the Seoul International Advisory Council, which gives advice to the city of Seoul for the transition of their energy system.

Job TAMINIAU

Dr. Job Taminiau oversees research that advances the mission statement of FREE (Foundation for Renewable Energy & Environment). He leads projects on 'best practice' energy efficiency policy, green technology investment, climate-sensitive economic development, and energy conservation awareness for public sector clients in and beyond the U.S. He completed his doctorate on climate change policy and economics at the Center for Energy and Environmental Policy (CEEP).

He has a multi-disciplinary background and his work covers subjects including energy finance, renewable energy and energy efficiency technology, (global) carbon markets, climate change policy, diffusion of innovation, transition management, and community utility development. Job manages the FREE Policy Brief Series and regularly publishes peer-reviewed papers and book chapters on a wide range of energy and environmental topics. For his work, he was rewarded with a first place climate policy thesis award from CE Delft (Netherlands), a second place in the MIT Climate CoLab contest, two University of Delaware Graduate Fellowships, and a FREE Minds Award. Job is always interested in engaging with other FREE Minds and is open for potential collaborations across the network.

Michael TOTTEN

Since the 1973 Arab oil embargo and price shocks, and after graduating with Honors from Yale University as a cross-disciplinary scholar, Michael P. Totten has dedicated his professional life to promoting innovative market strategies and governance policies that catalyze a solar powered economy comprised of highly energy and resource efficient buildings, industries and transportation sectors.

In the 1980s he pioneered comprehensive federal legislation, the Global Warming prevention Act (popularly known as the U.S. Productivity Enhancement and Export Competitiveness Act) which focused on accruing multi-trillion dollar savings opportunities through end-use efficiency gains. He also spearheaded the first Internet collaboration innovation network connecting state regulatory utility commissioners, for sharing methodologies focused on delivering utility services at the lowest lifecycle cost and risk via end-use efficiency gains and distributed generation.

In the 1990s Totten founded and headed the Center for Renewable Energy and Sustainable Technology (CREST), set up to harness the emerging global Internet communication and multi-media software tools for spurring best-in-play market practices and governance policies fostering zero-emission economic growth while accruing mega-scale monetary savings and biosphere benefits. CREST pioneered production and distribution of CD-based multimedia learning and decision-making software, migrated to the Internet when web tools emerged. By the late 1990s it was one of the largest Internet sites in traffic and accessible resources on energy efficiency and renewable energy. These several decades of innovative advocacy garnered Totten the Lewis Mumford Prize in 1999, given by Architects, Designers and Planners for Social Responsibility.

For the past dozen years Totten served as the Chief Advisor on Climate and Clean Tech at the global non-profit group, Conservation International. His cross-disciplinary initiatives focused on engaging scores of global corporations and national governments in getting them to adopt leadership practices and positions for achieving zero-net emissions. This was practically achieved by implementing portfolios of risk-minimizing, benefits-generating actions in operations and supply networks. Among his accomplishments included catalyzing Walmart's Sustainability initiative in 2004, beginning with assessing the ecological impacts, or "biosphere footprint", of their operations and supply chain.

Totten's more than 1500 presentations, articles, workshops and seminars over the past 40 years have illustrated and emphasized how Internet-based collaboration innovation networks (COINs) can leverage valuable insights from actual achievements worldwide, at far less cost and much faster speeds. In 2012 he launched the COIN initiative, ASSETs (Apps for Spurring Solar and Efficiency Tech-knowledge), to catalyze zero-net emission cities largely achieved by self-motivated citizens in their cities, companies, and campuses.

Frits VERHEIJ

Frits Verheij has been working in the renewable energy business and related areas like smart grids and energy storage, since the start of his career in 1987. Prior to joining DNV GL (then: KEMA), he held various positions at the research organisation TNO and was program manager at the Dutch Energy Agency Novem. Currently, Frits is Director Smart Green Cities for DNV GL – Energy. Additionally, he is Vice-chairman of the Board of Top consortium on Knowledge & Innovation (TKI) Urban Energy, and member of the Executive Board of USEF (Universal Smart Energy Framework).

Frits is an expert in working at the crossroads of innovation, energy policy, and strategy. He has been working for governments, utilities, industries, and other organisations in the energy sector. He knows how to work with the different interests of these stakeholders, as well as how to manage multi-client projects.

Marcel VOLKERTS

Marcel Volkerts is a Principal Consultant for DNV GL, where he focuses on smart energy systems. As a leading member of the Universal Smart Energy Framework design team and leader of the EDGaR Smart Gas Grids research project he works on creating a vision for applying smart, integrated energy systems on a large scale. In the EU-funded City-Zen project Marcel heads up the development of a multi-stakeholder serious game on the transition to zero-energy neighborhoods that provides input for roadmaps for the transition to smart green cities.

Before joining KEMA (now DNV GL) in 2011, Marcel enjoyed an international career in IT, working for various start-ups in both the Netherlands and the USA. As the director of quality assurance and manager of the database group of Florida-based internet security firm SafeCentral (formerly Authentium), he successfully established an international quality assurance and product development organization, before stepping into a role as an internal consultant for the CTO and COO, advising on product development, competitive analysis and product certifications. Marcel holds a PhD in experimental nuclear physics, earned through research done at University of Groningen, the Netherlands.

Michael WAIDNER

Michael Waidner is one of the pioneers of Cyber Security and Microsoft Academic Search lists him among the world's top scientific authors in the area of IT security and privacy. As a leading figure in Europe's security scene he has successfully founded new research centers and spearheaded innovative security paradigms like "Security at Large", which focusses on the security of complex real-existing systems. Waidner's broad scientific and entrepreneurial background makes him a unique expert for applied security whose council is sought by the enterprise world and the political sphere alike.

Currently, Waidner is the Director of the Fraunhofer Institute for Secure Information Technology (Fraunhofer SIT) in Darmstadt, Germany. He holds a chair as professor for Security in Information Technology at the Technical University of Darmstadt and is also the Director of the Center for Advanced Security Research Darmstadt (CASED), Speaker of the Center for Research in Security and Privacy (CRISP), and founding Director of the Fraunhofer Project Center for Cybersecurity at the Hebrew University of Jerusalem (Fraunhofer SIT/IL@HUJI).

He started in 1986 as a researcher at the University of Karlsruhe (now Karlsruhe Institute of Technology), Karlsruhe, Germany, where he received his Diploma and Doctorate in Computer Science. In 2004 he moved to Rüschlikon in Switzerland to join IBM, where he held various technical and management positions. As a Senior Manager he was responsible for IBM Zurich's security and software research projects, and for IBM Research's global agenda in security and privacy. During that time he co-initiated the IBM Privacy Research Institute, which he led until 2006, and the Zurich Information Security Center (ZISC), a joint research center hosted by the Swiss Federal Institute of Technology (ETH). In 2006 he joined the IBM Software Group in Somers, NY, USA. Until 2010 he was an IBM Distinguished Engineer and the Chief Technology Officer for Security, responsible for the technical security strategy and architecture of the IBM Corporation.

Michael Waidner regularly participates in scientific and technical advisory boards, program committees and conferences. He is a member of the ESORICS Steering Committee, and coinitiator of the ACM Workshop on Formal Methods in Security Engineering. Up to now he has co-/authored more than 130 scientific and technical publications in the areas of security, privacy, cryptography, dependability and fault tolerance. He has co-/invented more than 20 patents.

Eicke WEBER

Born on October 28, 1949 in Münnerstadt, Germany, Eicke Weber received his doctorate in physics from the University of Cologne in 1976. After research stays at the State University of New York, Albany, USA and the University Lund, Sweden, he habilitated in 1983 also at the University of Cologne. In the same year he took a job as professor at the University of California, Berkeley in the Department of Materials Science and Engineering. In March 2004, he was named chair of the interdisciplinary Nanoscale Science and Engineering Graduate Group.

In 1984 he received an IBM Faculty Development Award, in 1994 the Alexander von Humboldt Prize, and since 2002 he has been a fellow of the American Physical Society. In 1990 he was invited on the Tohoku University in Sendai, Japan as visiting professor, and in December 2003 he was asked to give the Zhu KheZhen talk at the Zeijang University in Hangzhou, China. Professor Weber was the first president of the Berkeley Chapter of the Alexander von Humboldt Association of America (AvHAA) serving from 2001-2003. Since 2003, he has been the founding president of the German Scholars Organization (GSO). In June 2006 he received the Order of Merit of the Federal Republic of Germany.

In July 2006, he became director of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg and simultaneously professor in the departments of mathematics and physics and of engineering at the Albert Ludwig University in Freiburg. In July 2008 he was appointed as director of the SEMI International Board of Directors. The Electrochemical Society ECS, San Francisco honored Professor Weber in June 2009 with the Electronics and Photonics Division Award. In October 2009, he was chosen to be an honorary member of the Loffe Physical-Technical Institute of the Russian Academy of Sciences, St. Petersburg. Since April 2010, Weber is a member of acatech, the German Academy of Technical Sciences, Berlin.

Robert WILHITE

In his role as a Managing Director in Navigant's Energy practice, Rob directs business strategy and regulatory advisory activities and serves as part of the Energy practice leadership team. He also supports the firm's growth with a focus on senior client relationships, engagement delivery, and industry thought leadership. Since starting his career 31 years ago, Rob has worked exclusively in the energy industry and brings a unique combination of technical knowledge and business strategy experience.

On a global basis, Rob has often advised energy clients in achieving increased efficiency in utility operations, grid automation, and technology strategy and implementation. He also supports utility strategies seeking new revenue growth and business expansion. In addition to utilities, Rob has also developed growth and market entry strategies for competitive retail energy firms, equipment suppliers, private equity firms, and industry policy groups.

Rob began his career with an 11-year stint at Florida Power & Light (FPL), where he managed State-wide energy efficiency programs and developed technical expertise in planning, designing, and overseeing construction of electric distribution facilities. Following FPL, Rob worked for the Electric Power Research Institute and then with Accenture. More recently, Rob applied the past 12 years of his career with KEMA (now DNV GL), where he was responsible for achieving growth, profitability, and operational performance objectives as managing director for the Americas, and as global director for all management and operations consulting. He developed KEMA's grid modernization advisory unit, overseeing expansion into one of the more successful practices within KEMA, but also positioned the firm as a respected market leader in this domain. He also co-authored KEMA's first book, *Utility of the Future: Directions for Enhancing Sustainability, Reliability and Profitability*.

Rob was recognized as one of the top 25 consultants in the U.S. by Consulting Magazine in 2009. He has also been cited as one of the Networked Grid 100 Movers and Shakers of the Smart Grid by Greentech Media in 2012, as well as participated in President Obama's Council on Jobs and Competitiveness in 2011.

Rik WILLARD

Rik Willard is the Founder and Managing Director of Agentic Group LLC, a multinational consortium of over forty (40) Blockchain, Digital Currency and related companies in the US, EU, South America and Canada, with representative offices in both London and Paris. He is recognized as a digital pioneer and serial entrepreneur, with a reputation of successfully introducing new and advanced technologies to international markets for over twenty-five years.

Prior to founding Agentic Group, in 2013, Mr. Willard was co-founder and Managing Director of MintCombine Inc. in New York City. MintCombine was the world's first think tank/startup incubator focused solely on digital currency technologies and the role of cryptocurrencies and tokenized blockchains within a wide range of business sectors. From 2010-2013, he consulted with a number of Fortune 500 companies and led a syndicate of investors interested in the convergence of social media and identity technologies.

Between 2006-2010 Mr. Willard consulted with the MGM Resorts corporation for global digital projects, including mobile and social media applications. During this time he was the lead consultant for internal and external digital signage and the lead on social media and mobile integration with signage, for application to MGM Resort properties worldwide, including their US and Asia properties. From 2001-2006, he was lead consultant to Winston & Company, designing display and back-end technology systems for many of the LED display projects in Times Square, New York City and working closely with major international brands such as Coca-Cola, Toshiba, LG. Anheuser Busch, Mars, and others.

In 1994 he founded Mediamerge, one of the first "dotcoms" in New York's emerging Silicon Alley. His clients included Calvin Klein Cosmetics, Lucent Technologies, Unilever and others. He sold his interest in that company to private investors in 1999. His first company, Beam Communications, was founded in 1990 and was the first company in North America devoted to HDTV outdoor advertising technology. Beam's clients and partners included Sony of America, Japan Broadcasting Company, Columbia Pictures, and Met Life.

Mr. Willard received his undergraduate degree from Howard University's School of Communications. He is a Fellow of the Foreign Policy Association, an Advisor to the Field Center for Entrepreneurship at Baruch College's Zicklin School of Business in New York City, a Board member of the Seidenberg Center for Computer Science at Pace University in New York, and a Blockchain Startup Advisor with the famous Silicon Valley incubator Plug And Play. He remains an internationally-sought speaker, featured at the Harvard Business School, the Kaufmann Institute, All Payments Spain/Australia, with numerous media engagements over the years including CNN, CNBC, and CNN International. Mr. Willard is also mentioned in Michael J. Casey and Paul Vigna's seminal book on the origins of the cryptocurrency movement *"The Age of Cryptocurrency"*, as being one of the initial venture catalysts of the current digital currency movement.

This study was commissioned by the Grand Duchy of Luxembourg on terms that limit the liability of the TIR Consulting Group LLC for the Third Industrial Revolution Strategy Study. The analysis and conclusions presented in the report result from the exercise of our best professional judgment, informed in large part by materials and information available from a variety of sources. Use of the report by a third party, for whatever purpose, should not and does not absolve such third party from using due diligence in verifying the report's contents for its own specific purposes. Any use of the document and any reliance on or decisions based on it are the responsibility of those individuals, organizations or businesses that use it. The TIR Consulting Group LLC makes no warranty or representation as to the content or accuracy of the content of the commissioned report and does not accept any duty of care or liability of any kind whatsoever to any prospective user, and is not responsible for damages, if any, which may be incurred by that user as a result of decisions made or not made, or any actions taken or not taken, based on the report.