NEXUS FUTURES SCENARIO: SMART SUSTAINABILITY

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SMART SUSTAINABILITY

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EXECUTIVE SUMMARY OF THE NEXUS FUTURES SCENARIO 'SMART SUSTAINABILITY'

In 2045 we find ourselves in a world where an alignment of economic, technological, political and environmental interests has fostered the emergence of a highly regulated, interconnected, circular economy. Artificial intelligence and virtual technology have slowly creeped into every aspect of society. We live in a world embedded with a *"comfortably numb"* belief that mankind's threats to the global ecosystem can be fixed through innovation.

But have we succeeded? Is our belief well-founded? We cannot know. Not yet. This is an anxious world, full of ambiguity.

The Smart Sustainability scenario describes to you, the reader, the journey we have all taken in the past three decades and where have ended up. We have witnessed in our lifetimes perhaps the greatest technology transition ever. A decisive shift has been made away from fossil addiction towards carbon neutrality. The energy transition is now a fact. Climate change challenges around water and the use of land have been confronted and overcome. Both individually and collectively, we have invested so much to mitigate the threats to our world. It is also true that we have handed over much personal freedom in return for a cleaner world and greater wealth. We now live anxiously in the hope that it was worth it.

The brutal fact is that accumulated stocks of carbon have never been more dangerous. The outlook is dreadful. 4-degrees warmer than 1900 by 2100. For decades, the promise of *"jam tomorrow"* empowered the convenience of business as usual. And now the bill is being processed by planet Earth. There is no longer time for payment on credit.

Our scientists are angry about being ignored regarding the need for adaption of our consumerist behavior. They not alone in being angry. Across the globe, countless individuals and communities have been left to pick up the pieces of a livelihood removed by AI and AV. Many more now live with the bitter tragedy of having lived a life that they now see was spent undermining the future of their progeny. And whilst humankind perseveres, for now, all around us we can see the unmissable signs that the flora and fauna of our ecosystems are in dire straits.

And yet, economically things are good. Over here in the greater Luxembourg region, they are very good. Lifestyle might be microscopically controlled, but most people are comfortable with that. Innovation in business models, driven by access on a large scale to multiple data sources, has led to the large-scale, cost-effective industrialization of a multiplicity of circular solutions. Energy and mobility are both renewable and cheap. Recycling design expertise and their related industries dominate the global market. Food is mostly sourced locally and remains relatively plentiful, thanks in large part to technology. Water on the other hand, as we in Luxembourg and Central Europe discovered to our cost rather late, is a precious resource whose use and re-use needs to be measured, and controlled, microscopically.

So, looking back, how did we get here? Where are the roots of our success and our current fears?

Back in the 2020's. against a backdrop of widespread ecosystem damage and sharply falling renewable energy prices, many governments and companies realized that it was desirable, plausible and profitable to embrace circular economic thinking. At the same time, AI providers recognized that complex, circular processes were ideal testbeds for their technologies delivering instant legitimacy

and return on investment. Concerns that the underlying societal dependence on continued economic growth had remained unchanged, were swept aside or condemned to ineffective studies.

The EU, supported initially by Japan, India, Chile, New Zealand, Australia and South Africa, initiated a Trade Related Environmental Tariff (TRET) regime. This regime rewarded circular processes with lower trade tariffs and increased, initially only marginally, non-circular processes. The regime required sophisticated monitoring and enforcement, but gradually it became operational and was widely credited with the accelerated adoption of renewable energy sources and improved recycling means.

The TRET regime combined with falling renewable energy prices to give our society many of the things we are grateful for and proud off today. Sustainable energy, and energy independence, is commonplace although we in Luxembourg only produce 60% of our needs. The rest is delivered to us by our neighbors who have made the necessary, rather heavy, investments in storage capacity and intermittency management.

Consequently, energy and mobility are both relatively cheap here in the Greater Luxembourg Region. Jobs, especially in the e-auditing, finance and circular technology sectors, pay well. The tax regime is not what it used to be, however. True, we still have relatively low income-tax, but digital taxation and associated VAT reforms have largely eroded any tax advantage of the Grand Duchy. In truth, we pay more in VAT these days than income tax. And much of that goes into so-called personal escalators where our consumption of food and water, and our generation of waste, is carefully monitored by an array of smart meters dutifully connected to our personal VAT profiles.

The tax advantage of Luxembourg doesn't really matter anymore anyway. The whole region has become an economic hub of circular innovation and regulatory prowess. Indeed, in many ways, the change has been a blessing in disguise. *Transfrontaliers* have grown in number, there are nearly 400,000 of them now. But, mercifully, most do not make the daily journey into the Grand Duchy. The lower tax differential, technology and the greater (cheaper) availability of construction space in the urban nodes close to the border all pushed down the daily mass movement. As a result, the quality of life for the nearly 1,3 million people now resident in Luxembourg itself has improved considerably.

And all that is the good news. Life in Luxembourg is tranquil. Water is managed, very tightly. The economy functions. Social welfare for the elderly is well in hand. The roads are quieter. But as the silent fauna of our forests permanently reminds us, there is a cloud. In fact, a rather dark one.

All around the planet are the visible eco-system consequences of the 3-degree journey to this point. The following decades will see probably even higher temperature growth before, maybe, falling back. The question on everyone's lips is *"are we too late?".*

Generational tensions are everywhere to see. Younger generations who largely disengaged from the political process over the past decades are awakening. They have misplaced their trust in technology and business as usual. The awakening is a rude one. There is a simmering anger towards the massed ranks of older generations. But above all, there is a sense of urgency.

We need to do something to reduce the accumulated damage of 300 years of industrialization. Deep adaptation is one route – a radical change in human behavior. But that is an anathema to the countless human beings across the planet who have successfully delivered a carbon neutral economy. Large scale, net reforestation is popular and is already underway, but many scientists are suggesting that mankind might have left it too late. Another technical fix perhaps?

Luxembourg is an integral part of a bigger global village that has achieved the astonishing and, yet, must now urgently do so much more or it will all have been for nothing.

SMART SUSTAINABILITY

WELCOME TO LUXEMBOURG IN 2045

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Life in Luxembourg in 2045 reflects, just like it does in 2019, a mixture of global, regional, local and human contexts[1].

To help the reader to quickly ground themselves in 2045, the Smart Sustainability Scenario starts with two personal stories. These short narratives illustrate what that life looks like, and feels like, through the eyes of those who live and work in the Grand Duchy.

all notable changes in climate in 2045 in all three scenarios are based on modelling average global carbon emissions over periods of 30-years; modelling hypotheses on climate attributes in the three scenarios in 2045 can thus exclusively be attributed to consequences of anthropogenic emissions between 1980 (1750 is when atmospheric CO2 started to accumulate). and 2010 (2020). Whilst any continuation of anthropogenic large-scale carbon emissions in the period from 2020 to 2045 will contribute to exasperate the problem

The first story is told through the eyes of Yasmine Yousif who lives in the Greater Luxembourg Region and who occasionally works in Luxembourg itself. This is an outside looking in narrative which shows how the day to day life of local *"Transfrontaliers"* has changed during the period.

The second story is told through the eyes of four people who live and work in Luxembourg – Marc, Claudine, Léon and Susanne. This is a local inside looking out narrative that explores the sense of identity of its inhabitants and how they have adapted to the changes that have occurred.

[1] All notable changes to the climate across the three Nexus scenarios are exclusively attributed to the consequences of accumulated, anthropogenic emissions that occurred between 1750 and 2020. Any continuation of such emissions will simply exasperate further the problem. The scenarios are not therefore driven by climate change *per se* but focus instead on contextual variables such as society's reaction to global environmental change, geopolitical changes, technological changes and cultural changes.

YASMINE'S STORY ……

Figure 2. Creative Commons CC0. https://www.maxpixel.net/Desk-Wait-Mural-Office-Woman-Computer-Monitor-2043432.

25 February 2045 - 08.15 hrs. Morfontaine, France.

Yasmine Yousif, Auditeur d'économie circulaire, wore a sigh of immense relief as her autonomous vehicle for the day rolled up outside her flat. Her grandfather was visiting, and she had endured an entire evening of him moaning and whining how things had changed since he had grown up in the Banlieues of Paris in the 1980's. How anyone could view those dark, polluting times positively, Yasmine could not imagine, but he stubbornly managed, nevertheless. Thankfully she had to work today, and so she gratefully threw her backpack onto the table, and climbed into the welcoming, cocooned environment.

"Make-up mode" she ordered as the vehicle pulled away. Windows frosted over, lights intensified, and a screen appeared with her face just above the table. This part of the road towards Luxembourg was reasonably straight and Yasmine was happy to use the extra time away from the flat, and her grandfather, to get ready for the day ahead.

Yasmine's morning schedule covered a new hotel project up at the lake near Echternach. Most innovations in the hotel business tended to be in or around the Mediterranean where water consumption, food logistics and environmental impact were more challenging. But, on this occasion, a large multi-national hotel chain had decided to use Luxembourg as a test bed for its "Green Circle" brand. Her large audit company was already the circular economy auditor to the chain and so Yasmine, as one of the company's Luxembourg agents, was called in to carry out the initial, exploratory audit.

Make up finished, Yasmine started to relax. Damn but her grandfather had been irritating. Sure, there had been mass unemployment

caused in the European car industry as electrification combined with autonomous technology. Previously some 12 million people, mostly men, had worked there and now that figure was closer to 2 million. Her grandfather, a former truck driver, and many of his generation back in Paris, had all lost their jobs. The much promised, and publicized, governmental re-skilling program never amounted to much – not that her grandfather was ever going to be flexible enough in the first place. She had said so last night and got the full load back. So much anger, so much frustration – no wonder there was a popular crisis every so often.

But what had really caused an argument over dinner was the way in which smart technology was being used to control more and more of people's lives. For Yasmine, with the possible exception of energy, the earth's resources were finite. What comes around must go around, again and again. The alternative was inequality, starvation and irreversible environmental destruction. That was her job, who she was. For her grandfather however, the earth was huge, infinite. If he wanted a lamb kebab then that is what he should be able to have without some bloody machine warning him about how much meat he had already consumed that month and how much tax he would be paying for the privilege. Only for the duration of his visit, it would be his granddaughter that would end up footing the bill for both his wasteful behaviors and cleaning-up his extensive medical consumption.

Yasmine grimaced. The generally accepted expert wisdom was that the vast industrial damage caused since the 1750's now had to be repaired. The global debate had moved on from ensuring continued global economic growth, creating opportunities for all and limiting environmental damage such as greenhouse gas emissions. Policy makers, industry and her own audit company, instinctively knew that only integrated circular principles, minutely monitored and controlled, could create a sustainable world and a more equitable society. And yes, that came at a price. The irresponsible freedom to misbehave and to pollute and destroy at will had to be checked. History had clearly shown that mere awareness alone was insufficient. Most people, people like her grandfather, had neither time nor the inclination to change their behavior unilaterally. Instead, behavior had to be influenced through on the spot prompts, better system design and financial incentives.

Needless to say – there was no aha moment in the Yousif household last night.

An alert interrupted Yasmine's reflections. The car was crossing into Luxembourg and the relevant employment tax regime had been engaged. She logged into her company's system to get an update from Ali, her AI supervisor. "Bonjour Yasmine, I hope you are well and in good form this morning. You should be well on time to start the exploratory Echternach audit. This luxury hotel project is quite new as you know although the 8 acres of ground they are using has a history of hotels. They have made a supplementary request late yesterday for a permit to implement a fixed charge per day per room rather than the more normal fixed room rate plus consumption charges. The Ministry tends to be skeptical about such requests, but the hotel management feel that they have compelling arguments. We shall see. Good luck". Yasmine nodded and terminated the call. Damn thing obviously knew from her body and facial language that today was not a day for small talk.

"View mode" she directed the car. The windows defrosted and she looked at the passing countryside and traffic. They had just passed the city medicaments cleaning station on the Alzette, south of Hamm where she had been working the previous week. Ali was right, not many on the road today, mostly small delivery trucks and the occasional old-timer that was still being driven around by wealthy locals. Used to be much worse according to some of her older colleagues – nearly 200,000 people crossing the border every day in the mid 2020's compared to a tenth of that nowadays. On the other hand, especially around the city, Luxembourg was now much

more built up to accommodate nearly twice as many people.

30 minutes later Echternach appeared and the car slowly made its way into the hotel complex. A young man, dressed in what looked like a formal hotel uniform, was waiting for her. After the usual greetings, she was led to the control room where she would start her audit.

Linear system control first. Get it out of the way. Yasmine pulled out her mobile assistant (mA) from her backpack, switched it on, and acquired the necessary system to system authority. A few minutes later, she started to get a briefing. Water collection, input, consumption and recycling systems were all aligned. The food cycle was a bit trickier, a few small non-compliances which could be easily fixed. Most of the equipment, furniture, artwork and fittings were on recycling leases so no problems there. Transport was simply connected up to the overall Luxembourg system. The building itself seemed to have the necessary sensory network and most of the materials used were either sustainable or had appropriate approvals.

Linear check complete, Yasmine left the control room to wander around. She always thought better when moving and seeing physical systems in context. Food was always a challenge in these posh hotels. "How much water is being consumed by these menus?" she asked her mA. "Split virtual from direct and compare to Luxembourg household benchmark". The answer was not very inspiring – a definite negative point. "Do they have the technical ability to implement the normal hotel charging mode? How are they dealing with non-EU visitors? Any assumption that looks odd? Maybe quantity and distance travelled?" Yasmine spent the next two hours firing off all kinds of questions, her main focus always on the relationships between systems rather than inside them.

At noon, she returned to her AV, sat down and called her boss. She quickly checked her clothes, straightened out a few creases and switched on the conference. Her boss appeared on the seat across the table, smiling. Françoise was around 50 years of age and always dressed impeccably. Even as an avatar, she could manage to be friendly and engaged. Yasmine reported her findings. The hotel did some smart circular things quite well, better even than some of the more advanced resorts in the south of France. There were some technical non-compliances and one or two, more serious, inter-system issues.

Her main concern was that the hotel chain had clearly copy-pasted a number of circular approaches from its Mediterranean resorts and that simply did not work out so well in a land-locked country. An illustration of this was that the new hotel system delivered significantly dirtier water to the local municipal water treatment plant. But that plant had not yet been upgraded to meet that challenge whereas such upgrades were standard around the Med. So, who pays for the upgrade in Luxembourg?

Françoise took note, asked a few follow up questions. The next step in the approval process would be with the hotel, then Yasmine would return and finally the ministry would issue its decision.

13.30 hrs. After a quick lunch, (somewhere close by to avoid any appearance of favoritism), Yasmine moved on to the afternoon job. Slightly more routine this one. Annual audit at a farm of ten data centers down south near Bettembourg. And then back home for one more night of grandfather.

HUNT FOR THE LION'S HEART ……

Figure 3. Schiessentümpel. https://www.visitluxembourg.com/en/place/misc/schiessentumpel-waterfalls

14 March 2045, Mullertal, Luxembourg

MARC

14 March 2045. 09.46hrs. 49°47'18.4"N 6°26'44.5"E. Osweiler. A lush waterfall of warm, recovered water rushed from the integrated shower rails onto the shampooed silver hair of Marc Nilles. 15 minutes later, Marc glanced out from the first floor of his bathroom window and smiled contentedly. For a short while, he looked down over his manicured garden upon rainbows dancing in the early sunshine upon the irrigation mists fed from the underground water storage he had installed ten years earlier. Later, as he donned his sleek bicycle helmet and small back-pack in the hallway, he made a quick mental note of his villa's energy, water and waste systems. Everything was fine and so Marc exited the door of his elegant villa at the edge of the woods and walked purposely towards the opening garage, unplugged one of the bicycles gathered there and made his way onto a path that threaded its way through the trees.

It was a beautiful summer day; not too warm and moisture levels were still heathy. Perfect for a cycle ride to the Lion's Heart. Marc had been looking forward to this for a number of days. The trip itself would take a few hours each way, weaving its way through the valleys that folded among the gently rolling hills that characterized this part of Luxembourg.

UNIT ST 55

10.00hrs. 49°50'07.3"N 6°19'48.5"E. Grundhof. Management control unit ST 55 completed its early river morning check. Flow rates were down 0,000015% on the previous day, a trend that had been observed since the last rainfalls in late February. Nothing unusual there. ST 55 issued the appropriate water extraction correction factors upstream thereby ensuring appropriate water levels at the Lion's Heart.

10.25hrs. Extraction unit ST-EU 108, serving a local farm upstream, reported intermittent performance. ST 55 sent a drone to investigate. 28 minutes later the drone reported back that a clump of vegetation had built up around the unit. A human was directed to clear it up but since today was a National holiday, no action would be taken until tomorrow morning. In the meantime, the drone had moved off to park atop a nearby 7G transmitter to charge its batteries.

Water quality was adequate for the time of year. Algae concentrations were below bloom levels. ST 55 concluded that the clump of vegetation required no further action.

CLAUDINE

11.00hrs. 49°36'16.3"N 6°08'40.6"E. Luxembourg City. Claudine Schlecter replayed the video of a monitoring drone on the Schwarze Ernz in the Mullertal. Not much else to do today – everyone at the Sûre river monitoring command department was off on holiday and she was on her own as human backup. She leaned back into the chair and inhaled deeply the aromas of her Sicilian coffee. A little non-local luxury she permitted herself now and again. A present to herself for working alone and a nice way to recover from the rush to work that morning.

Claudine lived alone in a flat in the city. The weather had been sticky warm all weekend and the only way for her to get some sleep was to wash of the accumulated sweat of the day with a quick shower. Not quick enough as she had rudely discovered when washing her hair that morning. The shower lights had turned from white to amber to warn her that her standard rate water credit had been exhausted and she was now on the higher rate. She had rushed to finish. The extra cost was annoying. So too was the information that, given the weather, her predicted consumption would be much higher than usual. But what really grated at was the frustration that the owners' association of her flat complex had recently refused to install a closed-loop system. Given her function, she knew for a fact that such systems would be cheaper in the long run but no, most of the other flat owners said they couldn't afford the initial retrofit costs.

As a result, Claudine still had remnants of shampoo in her hair. At least the coffee was nice.

Her attention returned to the screen. Odd that piece of vegetation really, couldn't make it out on the screen, the drone had recognized the blockage pattern from around a hundred meters before flying off.

Out of curiosity and boredom, Claudine directed the drone to stop its recharging cycle and to have a closer look. What was it exactly and where did it come from? A few minutes later, the drone was taking close ups and Claudine was discovering that the vegetation was Vicia Faba – Fava Beans. Who had started to grow that in the Schwarze Ernz? Not that there was anything wrong with it, many vegetables that had previously grown in the Mediterranean area were now thriving in Luxembourg. Curiosity satisfied; Claudine started to review the early morning water quality data.

AI EXTRACTOR

12.00hrs. 49°49'34.6"N 6°19'43.3"E. Berdorf. An independent water extractor unit reviewed the different flows from the morning's work. It had measured the river flow around midnight and then gradually upgraded its ongoing,

clandestine extraction process. It was important for the unit to increase its daily water extraction by no more than 1 liter, but it had been doing this for the past ten years and so the current extraction rate of around 3000 liters per day had remained undetected by the river monitoring Department. They simply thought that the river catchment area was deteriorating slightly for purely natural reasons and consequently they simply adjusted slightly extraction rates from the official units that were dotted all along the river.

The water filtered into a cascade of underground storage modules that acted as a buffer for the farm. From these modules, water was extracted and distributed to the relevant planting areas. The energy source and initial distribution network operated fully independently, although the end distribution points were shared with the official water extraction system, albeit downstream of any government monitoring device. The official extraction systems at the farm continued to operate in parallel so as not to raise any suspicion. The outcome was that this particular farm, which was fully organic and also used the latest technology, had higher yields.

LÉON

12.04hrs. 49°47'28.6"N 6°18'31.9"E. The Hôtel-Restaurant at 1 Rue de l'Ernz Noire was beginning to fill up for lunch. Reservations only on this National Holiday. Léon Hausemer could clearly hear the sounds of the band practicing at the cascades from across the Mullerthal. It was going to be a busy day.

Léon, born to a Portuguese mother and a Luxembourgish father, had gone to hotel school on the grounds that almost every other job was being threatened by automation. People always wanted food and a bit of social contact and Léon was very good at both. The one thing he had not counted on however when he embarked on this career choice was the extensive circular system knowledge he now needed to do his job. As a result, Léon found himself at the start of every meal checking on a wide range of sustainability and compliance criteria. The proportion of local food was one such criteria. Thank God, he thought to himself as he reviewed the menu, for Susanne's organic farm up in the hills. She was prolific and always seemed to have such a wide variety of vegetables in almost every season.

Léon adjusted the menu to ensure compliance and released it to the tables and staff. Fairly easy to estimate on a day like today. Tables were fully booked with three sittings planned for the day. Volumes made planning more accurate. Léon looked around the restaurant, put on a broad smile and started towards the regulars seated at one of the window tables.

SUSANNE

12.15hrs. 49°49'55.6"N 6°18'27.6"E. Beaufort. Susanne Kirsch was a physically rather stern, imposing woman as well as being quite an impressive farmer. She had studied agricultural science at the University of Wageningen in the Netherlands. As a result, she was in the vanguard of modern, organic farming methods in Luxembourg – an original eco-warrior putting her deeply held beliefs into practice. Her army of drones patrolled her farm with a military intensity looking for any disease as well as the slightest opportunity to accelerate growth.

Susanne frowned. Something, a large bird perhaps, had torn at her recently planted Fava bean patch. Susanna did not mind birds and small mammals feeding off her farm, but this seemed to be wonton destruction. Maybe the bird, if that is what it was, had thought the plants would make good nesting material. She made a mental note to have a drone park itself overnight in the general area to see if she could learn more. In the meantime, she had to attend to the maintenance of her water extraction unit – the one that only she knew about.

When Susanne had been in Wageningen, she had met some friends from Amsterdam who were involved in building AI water monitoring

systems. They had tipped her off that these things would be soon widespread and also explained to her how they worked.

Her friends had also offered a possible hack. And ten years ago, she had said yes.

In fairness to Susanne, she originally thought to acquire the extensive underground water system as a buffer against climate change. The river was becoming an unreliable source of water and so by investing in water storage as well as rain capture, Susanne thought that she could have a more reliable business. Organic farms were difficult to run at the best of times and these installations were common sense.

It was only later that she decided not to mention its existence to the authorities. The man from the river command center had been so officious during his first control visit, lecturing her as if she was stupid or something. In a fit of pique, she remained silent about the installation and now, many years later, she maintained that silence. For Susanne, water for food had a higher priority than water for all those stupid data centers.

MARC

12.30hrs. 49°47'09.3"N 6°17'53.3"E. Marc Nilles was making his way to his goal – the national celebration of the Schiessentümpel.

As he moved along the wooded forest, he couldn't help but notice how few insects has landed on his clothes. As a child he had cycled this route many times and had always ended up covered in a rich collection of small flies and insects that hovered beneath the foliage of the trees.

The observation saddened him. Europe, including Luxembourg, had planted hundreds of millions of trees in the past 25 years in an attempt to capture carbon and somehow reverse the effects of 250 years of industrialization. He needed to believe that this and many other efforts, including a super hi-tech investment in water management, had had some positive impact. These efforts had undoubtedly helped society to avoid some pretty nasty bullets, but the underlying fauna and flora ecosystems had yet to recover and things were still on a knife edge. The environment he glided through was green and beautiful, but it was also grimly silent.

He turned the corner and there they were. Schiessentümpel, the cascades that so characterized Luxembourg. The Lion's Heart of the country. Everyone could vividly remember when the cascades simply stopped flowing. Now they were restored to their natural, vibrant beauty.

Marc smiled, parked his bike and joined in the celebrations.

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THE SMART SUSTAINABILITY SCENARIO

1. GLOBAL CONTEXT - A TECHNICAL FIX BRINGS ITS OWN PROBLEMS

1.1. THE CIRCULAR ECONOMICS OF TECHNOLOGICAL REVOLUTION

The past three decades have seen the steady, step by step, emergence of an economic model dominated by two, complementary, technological revolutions. Artificial intelligence (AI) has expanded into a vast array of human activity and employment bringing global economic benefits and increasing inequality. In parallel, the principles of circular economics, first popularized by the Ellen MacArthur Foundation in the 2010's, have generated the collection of vast quantities of data to be deployed in increasingly sophisticated, sustainability systems. Systems that can only managed using AI.

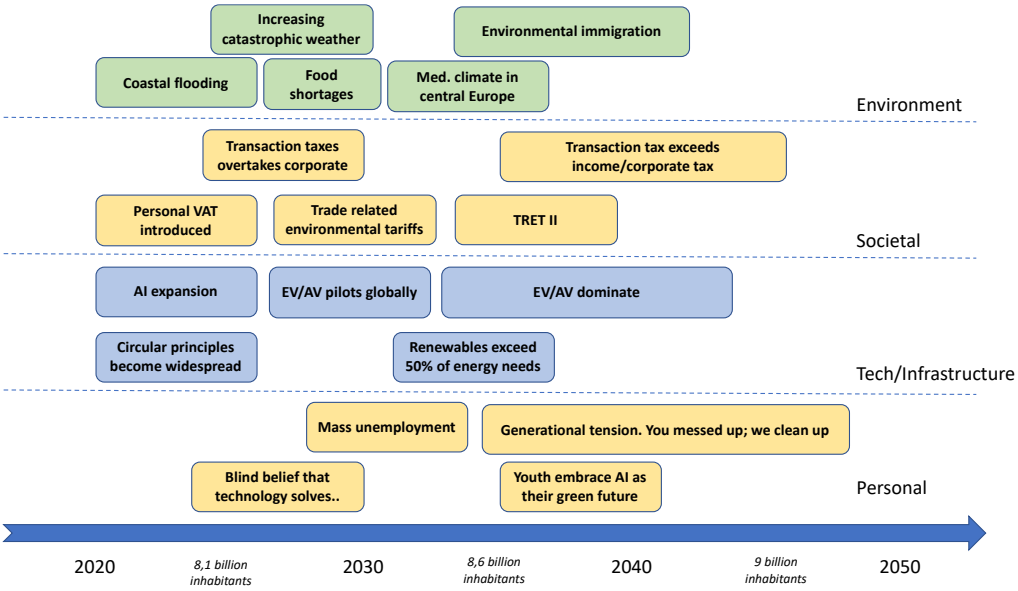

Figure 4. Timeline of key developments in the Smart Sustainability Scenario

These twin industrial revolutions have been made possible by a global alignment of economic, political and environmental interests[i]. Against a backdrop of widespread ecosystem damage and sharply falling renewable energy prices, many governments and companies realized that it was desirable, plausible and profitable to embrace circular economic thinking[ii]. The days of "light-touch regulation" and "market knows best" were left behind as major companies, and their lobbying proxies[iii], decided that the perpetuity of their businesses depended on some form of market regulation[2]. The Coronavirus crisis of 2020 reinforced the determination of those who held the belief that environmental measures had to go hand in hand with economic growth[iv]. In 2020, global GDP dropped by around 3%[v], US unemployment shot up to 15% in just one month[vi], the bottom dropped out of the fossil fuel market and still CO2 emissions remained stubbornly high at 92% of historical levels[vii].

At the same time, AI providers recognized that complex, circular processes were ideal testbeds for their technologies delivering instant legitimacy and return on investment[viii]. The Coronavirus crisis enabled these providers to sweep aside concerns about privacy and data protection by cloaking

[2] "If business in partnership with government cannot adapt the global economy to avoid the worst impacts of climate change and generate inclusive growth that lifts people out of poverty and expands the middle class, then the negative consequences will be vast". David Solomon, CEO of Goldman Sachs writing an opinion piece in the Financial Times, 15 December 2019.

themselves in the guise of medical saviors[ix]. Any concerns that the underlying societal dependence on continued economic growth had remained unchanged, were swept aside or condemned to ineffective studies[x].

The EU, supported initially by Japan, India, Chile, New Zealand, Australia and South Africa, initiated a Trade Related Environmental Tariff (TRET) regime[xi]. This regime rewarded circular processes with lower trade tariffs and increased, initially only marginally, non-circular processes. Resource rich countries could thereby export raw materials, such as ore and food, at lower tariffs, provided the end user was a part of a larger circular process. The regime required sophisticated monitoring and enforcement, but gradually it became operational and was widely credited with the accelerated adoption of renewable energy sources and improved recycling means.

Overall, TRET Member States benefited economically from the regime and gradually the World Trade Organization took over with support of the US, China and most African States[xii]. As TRET II negotiations proceeded, AI and circular technology marched hand in hand and, what critics have called *"circular creep"*, became widely adopted across industrial processes, service industries and individual households.

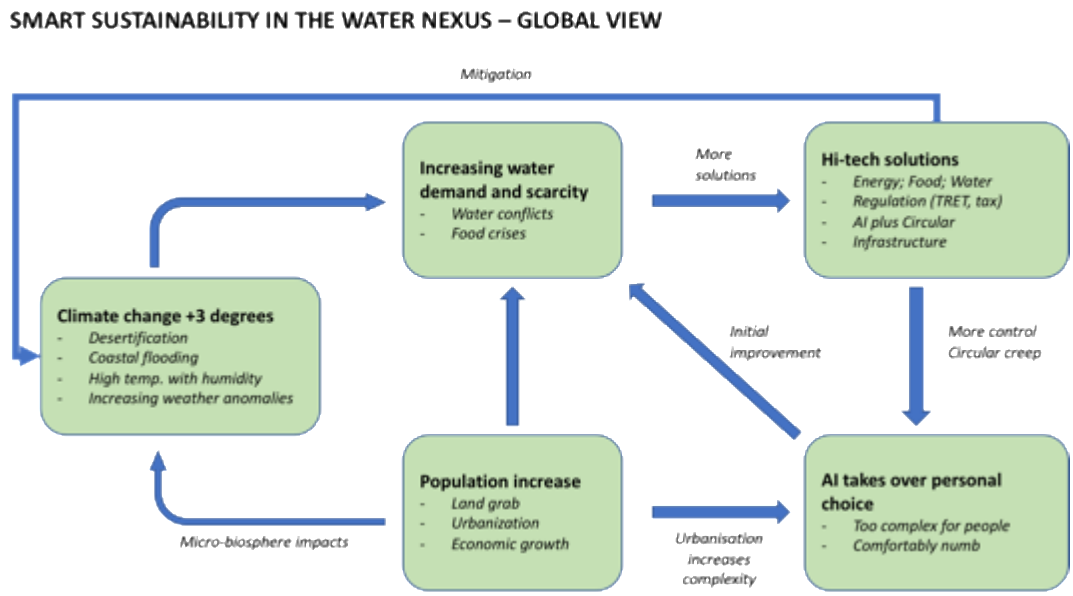

Figure 5. How AI gradually takes over personal choice in Smart Sustainability Scenario – Global model

As a result of these various changes, Europe in general[xiii], and the European Union in particular, have fostered the emergence of a highly regulated, interconnected, circular economy[xiv]. AI has slowly infiltrated itself into every aspect of society[xv]. Virtual technology has become so widespread that on-line transaction taxation is now more important than income and corporate tax combined. Indian[xvi], European and Japanese AI recycling design expertise, and their related industries, dominate the global market. And the blockchain technology that these industries rely on has slowly encroached into an increasingly difficult food (and its related water) market as a means to combat fraud and secure provenance.

1.2. THE NATURE OF GLOBAL COMPETITION

The fixation on technology hides a deeper, more fundamental truth in this world. It is a society driven by different actors seeking to project economic power over a space they wish to influence. Multinationals capture markets through new and innovative business models. Trading blocks and

Nation States use economic rationale to maintain and project their power and influence. Historical inequalities between regions are reinforced. The “winner takes all” opportunities offered by AI are primarily directed therefore to support the projection of this economic power.

And therefore, despite these technological advances, significant concerns remain. Technology has not been the silver bullet for the environment that many had hoped. Many of the benefits gained have been wiped out by increased growth and consumption. And a number of regimes have exploited the intrusive nature of the new technologies for their own, darker, purposes. Above all, global ecosystems remain in a fragile, precarious state.

Challenge Box 1. Can we continue?
The Smart Sustainability scenario takes the current business as usual system logic, expands it, re-enforces it and then takes it through to a plausible outcome 25 years later. But would, or could, society continue like that? Would the current performance based, economic model continue to run the show in a world were ecosystems are collapsing? Would society remain in stasis when confronted daily by a materialism that is a visible virus to the hard-drive of humanity?

In conclusion, for the past 30 years the global economy has continued to develop and transmute in reaction to various technical, demographic and environmental forces. Society is still basically a reward performance model. The only nuance is that performance is increasingly more than financial[xvii]. Other measures such as circularity (cradle to cradle) and environmental impact are being integrated into the overall performance scorecard.

The bottom line however, despite greenwashing protestations to the contrary, is that economic growth (more GDP) is “good”.

1.3. ENERGY AND INDUSTRY

The world has transitioned to renewable energy sources at an accelerated rate due to a potent combination of market forces, health issues and environmental concerns. Ever since the mid-2010’s, unsubsidized renewable energy from wind and sun has been cheaper than fossil fuels[xviii]. Economics of scale and continued technological advances meant that, by the early 2020s, the vast majority of new electricity generation projects were renewable. At the same time AI was improving the demand-supply relationship thereby reducing the intermittency challenge. Notwithstanding these improvements however, large-scale energy storage solutions were still required against the backdrop of mobility and much of heating switching away from fossil fuels and going electric[xix].

During the 2020’s and 2030’s, major fossil fuel suppliers, in vain, sought to sharply reduce their prices. But closing the cost gap with renewables that had become a factor of 10 and beyond was never going to be easy. Even hydrogen, generated from surplus renewable energy, was cheaper than natural gas. Added to that was the precarious state of the world’s biosphere and a political drive to reduce energy dependence from unsavory regimes. So, by the early 2030’s, an economic tipping point had been reached whereby decommissioning existing fossil-fuel power plants, well before the end of their life-cycle, saved money.

Overall, by the mid-2040’s, global energy consumption has increased significantly due to electrification and increased demand from technology. In 2045, electron to molecule to electron

(e2m2e) services are widespread and feed into energy storage, industrial processes, aircraft fuel and heavy shipping requirements.

If the electricity sector and automotive industries went through a period of deep and unsettling turbulence[xx], the same could not be said the IT and telecom sectors and mobility infrastructure operators. For them, business boomed. Demand for new 'smart' city mobility solutions has never been higher, despite a growing jurisprudence around AV/AI liability risks. Niche areas such as cyber security, blockchain technology and IoT have joined in along for the ride.

Companies with ready access to large scale finance were easily able to form public/private partnerships with cities, local regions and national governments. Innovative sustainability platforms around food, energy, water, mobility and housing abound in today's world. The previous political reluctance to embrace aggressive pro-sustainability business/taxation models faded away with an ever-decreasing rate of house[xxi] and vehicle ownership[3] among city dwelling citizens and the promise of a better quality of life.

1.4. FEEDING THE PLANET

The relative success of the energy transition spurred confidence that technology could deliver similar results in feeding the planet[xxii].

Boosted by low energy prices, artificial fertilizers based on sustainable ammonia production dominate today's market. This new source of fertilizer, although still chemical, is combined with microbial technology targeting seed treatments developed from plant microbes. AI and other digital technologies also make their way through the farmyard gate and into food production. The application of these different, smart technologies increases yields and sharply reduces dependency on pesticides, even under all too prevalent stressful growing conditions. Widespread local data collection is combined with climate patterns and seed databanks. This determines local decisions on seed selection, planting density and depth, and harvesting.

Smart technology[xxiii] also delivers the de-commoditization of agriculture by enabling different products from different suppliers to be identified with a unique fingerprint[xxiv]. The resulting differentiation and traceability have spurred the growth of niche markets across the different product ranges in the same way as occurred for coffee beans in the early decades of the 21st century. This agricultural DNA technology has been widely adopted under the TRET regime and filtered its way into circular economic design.

Initially, regulation and taxation applying circular design principles involving food was only applied to major hotel and catering providers and the food processing industry. But the long standing and widespread data collection of individual purchases at major supermarkets meant that it was a relatively small step to apply circular economic principles to households. Starting off, this was on a voluntary basis with financial or informational incentives. However, step by step, as widespread acceptance of the value of this approach took hold, household food consumption data was integrated into the broader regulatory framework.

[3] The idea that car sharing significantly reduces the requirements for parking space can be found back in a number of city initiatives. The Momo car-sharing initiative in the city of Bremen presented at the World Expo in 2010 is just one example in Europe. The underlying idea is that car sharing agreements with residents of new developments in inner city and metropolitan areas are encouraged in exchange for reducing parking infrastructure. The idea is especially relevant in fast growing urban areas such as the Luxembourg region as outlined in this scenario. Car sharing policy guidelines were developed for the EU in relation to the Bremen initiative cf; https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/momo_car-sharing_car_sharing_guidelines_for_public_authorities_en_en.pdf

Across the world, food production grappled with the consequences of climate change[xxv]. Food production increasingly anticipated changes in global weather patterns and, in the center of Europe for example, this has led to a very different form of agriculture. One that depends on the micro-control of water, sustainability finance and a strong regulatory support for local produce.

1.5. THE STATE OF GLOBAL ECOSYSTEMS

The precarious nature of the earth's ecosystems is most starkly visible in the growing frequency of extreme weather events. Economic growth across the world has led to greater consumption of goods and, whilst the proportion of raw materials from virgin mining has declined sharply, the difficult reality is that average temperatures have relentlessly moved higher and higher in line with greater energy generation, land use and consumption. In the Central European area for example, Mediterranean weather patterns are seen more frequently with longer periods of drought. This is especially visible in the summertime when dangerous spells of hot, humid weather threaten children, the elderly and the infirm[4].

In this world the biosphere is a constraint that serves the Technosphere and mankind. Environmental changes are seen as a challenge to be managed, where technical mitigation is the *"goto"* response. Waste is seen as an economic opportunity to be exploited. A gap to be exploited in the normal cradle to cradle logic.

Across the planet, the past 30 years have seen the emergence of business models being developed to exploit these circular gaps or opportunities[xxvi]. There has been a shift away from value chains towards value constellations. From adding value to retaining it. And the greatest potential in value creation, and retention, is around data and ICT.

To feed a growing global population with shrinking farmland, food products are now being designed to be circular and to return to the soil as biological nutrients. Waste is food is good business. Circular economics has meant, at least in Europe, that even landlocked (wealthy) cities and countries like Luxembourg are able to get the vast majority of their required resources from an area within 100 km.

Globally, city authorities have seen the combination of electrification and AV/AI mobility primarily as an opportunity. Air pollution mitigation, more so than CO2 emissions, was an important consideration, driven by health concerns and incessant legal activism. But so too was the possibility to have less congestion[xxvii], safer roads and more space in densely populated city centers.

Cities may be cleaner, nicer, places to live but the cumulation of C02 has led to a grim outlook in terms of yet further global warming and all its domino effects. The 'official' policy debate in the 2040's is at long last focused on repairing the damage already made to the planet, rather than avoiding causing any new damage.

Sadly, the debate on the role of the economic thinking that brought the planet to this point, simply does not compute with the modern, policy cyberborg.

This is not a world that is very resilient. Shocks to the ecosystems, usually climate related, create great misery and suffering. Technology does allow for a high speed of reaction. Nevertheless, inequality between Nations means that this valuable capability is reserved for the privileged few.

[4] There are many studies to support the net increase in deaths in Europe due to climate change. These studies point to the conclusion that the reduction in cold-related mortality is far exceeded by the increase in heat-related mortality. In the 2012 book, Integrated Risk Governance, edited by Peijun Shi et al., this net increase was estimated at 25,000 per annum from the 2020's onwards. The potential increase was higher in south Central Europe and southern European regions more generally.

Furthermore, the technologically driven, mitigating action rarely, if ever, contributes to redundancy and/or resilience[xxviii].

Identified risks are classified, mitigated, managed and controlled by AI. Unidentified risks are simply ignored. Society has outsourced the need for resilience to automation and most people are *"comfortably numb"* about that.

1.6. WEALTH AND INEQUALITY

In many ways, inequality between and within Nations has been the main victim of the technological focus of the previous decades. The bling-bling of technology, even the focus on repairing the damage already caused, has kept the debate on inequality away from the headlights.

This is a world where wealth and well-being are tightly related to ownership of capital, healthy agricultural land and technology. Money buys access to food in a declining biosphere. Urbanization has been accelerated in a desperate search for more land – either for carbon capturing forests or intense agricultural development. And despite cities no longer being exposed to high levels of toxic pollution, the highest levels of well-being are not in the metropolitan areas, they are in those areas close by. Nevertheless, the stark, and real, fear of a planet going into shutdown mode prevents any serious action that might resolve such inequalities.

Globally, mass migration driven by the inexorable momentum of climate change dominates the relationships between Nations. High levels of migration are framed as climate challenges rather than being driven by inequality. The current outcome is that migration levels are high within trade-block regions rather than between them[xxix]. Large trading blocks of weaker Nations, such as the African Free Trade Area, have been forced to exchange migration controls, food and land for access to technology and economic assistance. These deals have allowed economically wealthier Nations to further reinforce their power and avoid the worse consequences of their historical actions. They have also led to the absurdity where those with land are not sustained by it.

The brutal fact is that economic growth, very specifically smart growth, has reinforced and expanded almost all existing forms of inequality. The democratic process has been undermined by increasing technological and systemic complexity. And all too often, the inter-dependence of societies and their overall well-being, have been traded off in the search for the wealth of capital.

The world has become smart. It has a long way to go before it becomes wise.

2. EUROPEAN CONTEXT – THE WEALTH OF NATIONS AND TAXATION

2.1. EUROPE STRUGGLES WITH AN AGING POPULATION AND TAXATION

The technological disruption of many industrial and service sectors has resulted in a fundamental, and permanent, shift of wealth away from the physical world towards the virtual world[xxx]. The trend, first observed in the early 2000's, of internet disrupters turning upside down entire sections of the economy and capturing the lion's share of the value has continued its aggressive march[xxxi]. From mobility to leisure to housing to food consumption - every aspect of modern life is dominated by virtual business models. These business models make use of the physical world, largely without ownership of physical property (i.e. they have scale without mass). The business models achieve this outcome by creating value constellations around which they transfer wealth to the central processing chip.

One of the most significant challenges posed by this trend was the existential threat to the revenues of Nation States[xxxii]. European Nation States, such as France and Germany, with aging populations saw themselves caught in a vice. On the one hand, their pay-as-you-go social security models were desperate for more tax revenue as pensions, health care costs and long-term care costs for the elderly soared[xxxiii]. On the other hand, innovative un- and repacking of cross-border services was reducing State revenue from company taxation by billions of Euros per year.

And all the time, throughout the 2020s and 2030s, the very same States were hit by sustained mass unemployment in the mobility[xxxiv], administrative and legal sectors.

Something had to give and in the end tax innovation in France and Scandinavia was quickly followed by others. The universal social security framework – the very essence of the Nation State in Europe – finally acquired the necessary funding through two main changes. The widespread introduction of wealth taxes and, more significantly, targeted taxation of a wide range of internet-based transactions.

Challenge Box 2. An aging society, mass layoffs and democracy

The Smart Sustainability scenario posits that most of the developed world (including India and China) is hit by a wave of mass layoffs due to the industrial revolution brought about by Artificial Intelligence. The classic economic assumption, taken over for the purposes of this scenario, is that other forms of employment emerge to replace those lost. There is unrest, but business as usual dominates.

The difficulty is that these mass layoffs occur during a major demographic shift towards an aging society and the cost re-skilling for most employees is significantly higher. Previous industrial revolutions occurred in very different circumstances.

Does the classic economic assumption hold true against the turbulent backdrop of an aging society. How would democracy behave? Traditionally, older voters vote disproportionally more than younger ones and they vote conservatively. Would politicians be able to pay any attention whatsoever to the social impacts of AI? What kind of impacts would a negative job outlook, reduced retirement perspectives and a highly uncertain environmental future have on democracy? And what kind of impacts would these circumstances have on States that are not democracies?

These targeted transaction taxes required considerable data collection by tax authorities. In turn, this forced them to establish competence in data mining and AI[xxxv].

Needless to say, it did not take long before this competence became a political opportunity.

Anxious to avoid popular backlash, many politicians supported the introduction of a personal VAT number that would allow the poorest in society to pay less, not only in income tax but also in transaction tax. Environmentalists too seized on this new governmental capability to lobby intensely, and ultimately successfully, for nuanced taxation of smart, sustainable products and services[5].

[5] The idea of a personal VAT number for transactional tax is also to be found back in the 2018 Rifkin report for the future economic development of Luxembourg. The OECD has recently breached more generally the taxation challenge posed by new business models. (References 7 and 25). AI is currently deployed in VAT collection systems of Russia, Portugal and some Scandinavian countries (Reference 42).

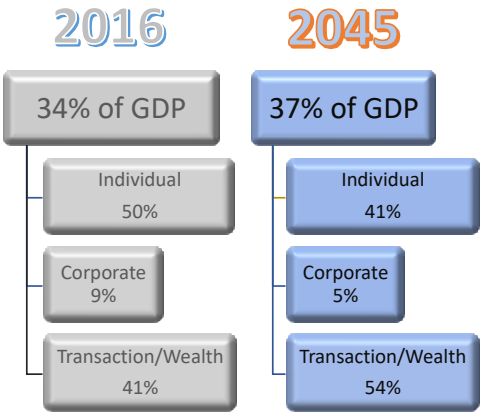

Figure 6. OECD tax revenues – 2016 versus 2045 - as a proportion of GDP[6].

In Europe, whereas at the end of the 2010s the level of tax revenue levied from transactions was similar to that received from personal income and corporate taxation, this picture had radically changed by 2045[xxxvi]. For most European States, tax revenue had become dominated by an increasingly sophistic set of transaction levies backed up by a wide variety of cross-border distribution agreements. Personal income and corporate taxes have been reduced to playing a supporting, but declining, role. And whilst rich individuals could continue to deploy their tax avoiding battalions, the same could not be said of their corporate counterparts.

This was not a painless transition. The social security framework itself did not escape unscathed and the funding shortfall that has loomed large over the past 30 years also impacted the post-war roots of the welfare state. This was a period has saw the gradual corrosion of the concept of pension replaced by, part-time work and other social activities well into old age. AI and mass unemployment have created fertile ground for a universal income, but tax shortfalls have kept States wary of implementing such utopian policies.

This contextual shift across global, and European, taxation systems had a profound effect on a number of countries that had attracted large corporations with low corporate tax regimes[xxxvii]. The UK, Ireland, The Netherlands, Luxembourg and Switzerland all had to adapt to the new reality. And they got precious little sympathy from the big three EU countries of Germany, France and Italy – each of whom had both aging populations and massive turbulence in their respective car industries.

2.2. ENERGY IN EUROPE

The European energy sector, like many of its global counterparts, has undergone enormous disruption.

Overall, fueled by basic economics, new regulatory frameworks and sustainable finance policies, (especially from the ECB and the EIB), renewable electrification of the European economy expanded at a rapid pace. New and emerging energy conversion services are in high demand. The overall share of electricity as an energy form has increased across Europe. Mobility has been a key driver as the cost of ownership differential between the combustion engine and other, cleaner, forms of automotive propulsion reached a tipping point towards the end of the 2020s. Large fleet users were among the first to shift electrification but the rest of the market soon followed[xxxviii].

[6] 2016 data is from the OECD 2018 revenue statistics report. Luxembourg had an overall tax revenue of 38,1% of GDP in 2016.

And, although today renewable energy is relatively cheap, its associated energy storage and transformation services are not. Consequently, business models, including in manufacturing, have been developed to exploit the availability of very cheap, but intermittent, energy availability.

2.3. EUROPE AS A REGULATORY SUPERPOWER

2045 is a world of complex, interrelated and fragmented regulation. Regulations related to sustainability, backed up by swaths of big data and AI, are used to steer over-riding policy goals related to the environment, scarcity management and competitive advantage. EU auditing and compliance industries have exploded in importance. This increase in regulatory compliance has been aided, in no small part, to the ability of the sector to keep costs low. The sector has managed to do so through increased automation in the areas of rules engines, blockchain and data mining. The outcome is that traditional accountancy is now supplemented by a range of circular accountancy rules which are applicable both at the company and EU level.

This sophisticated regulatory environment has strongly favored global players, regional champions and incumbents who can afford the requisite staffing and IT infrastructure. But attitudes to work and entrepreneurship in key economies with a growing, relatively young population (Africa, South America) has meant that large companies find it very difficult to retain talent. As a consequence, innovation through start-ups and SMEs remains strong even if a common model is for large incumbents to buy in these innovations after they have proven their worth in practice.

Challenge Box 3. Can "green" be defined?

The Smart Sustainability scenario posits that regulatory change encouraging sustainable behavior is desirable, politically acceptable and feasible.

Feasibility is perhaps the most challenging of these assumptions. What will the European taxonomy for sustainability look like? Which standardized indicators for all European companies will be put in place to allow for the evaluation of their environmental performance? How will these indicators be updated in the light of technology and science? Who will collect the data? Who will audit the taxonomy? How will enforcement work?

Many initiatives are underway today[7]. The new head of the European Central Bank wishes to make climate change "a mission-critical" priority. Her central banker colleagues are in full agreement that climate change represents a "systemic risk" to the global financial system. The European Parliament recently declared a "climate emergency". The political will, for now, appears to be present. But how does one define "green" in the world of finance and regulation?

The EU's role as a regulatory super-power has not been restricted to the Trade Related Environmental Tariff (TRET) regime. From 2020 onwards, the European Union enacted a series of ambitious policies and regulations for the implementation, on an industrial scale, of an interconnected, smart, electrified economy based on renewable energy with sustainable heating, cooling, housing and mobility. As a direct consequence, the development of investment lines in energy services, sustainability, autonomous vehicles, cybersecurity and services relying on high-speed telecom standards (5G through to 7G) was accelerated.

[7] See for example, "France seeks compulsory green reporting standards for EU companies." Victor Mallet, FT, 29 November 2019.

Investments that stray too far outside this policy framework find it difficult to attract the necessary finance. This is the result of major disincentives as central banks, stock markets, sovereign wealth funds, pension funds and development banks have all integrated tough sustainability requirements into their risk assessment and portfolio management models.

Across the European continent, the collective impact of these regulatory changes has led to *"more Europe"*, not less, and this has not always been welcomed. The accelerated introduction of mass unemployment across a wide range of sectors such as mobility and legal services has caused many a (occasionally violent[xxxix]) backlash over the past decades.

Nevertheless, the machine of progress, global competition and a sense of the inevitable pushes this agenda forward. And broadly speaking the ongoing, if not always healthy, alignment of interests between the European political class, legal and environmental activism, the regulatory industries and key industries such as IT, mobility and energy remains firmly glued together[xl].

As a result, bit by bit, regulation by regulation, environmental setback by setback, the general public drifts towards a resentful acceptance.

3. THE LUXEMBOURG CONTEXT

3.1. CENTER OF A BOOMING REGION, DESPITE TAX REFORM

If anything, with the benefit of hindsight, Luxembourg was in fact reasonably immune to the corrosion of its relative tax advantage. Corporations, especially those involved in AI and data, still had some tax and regulatory advantages.

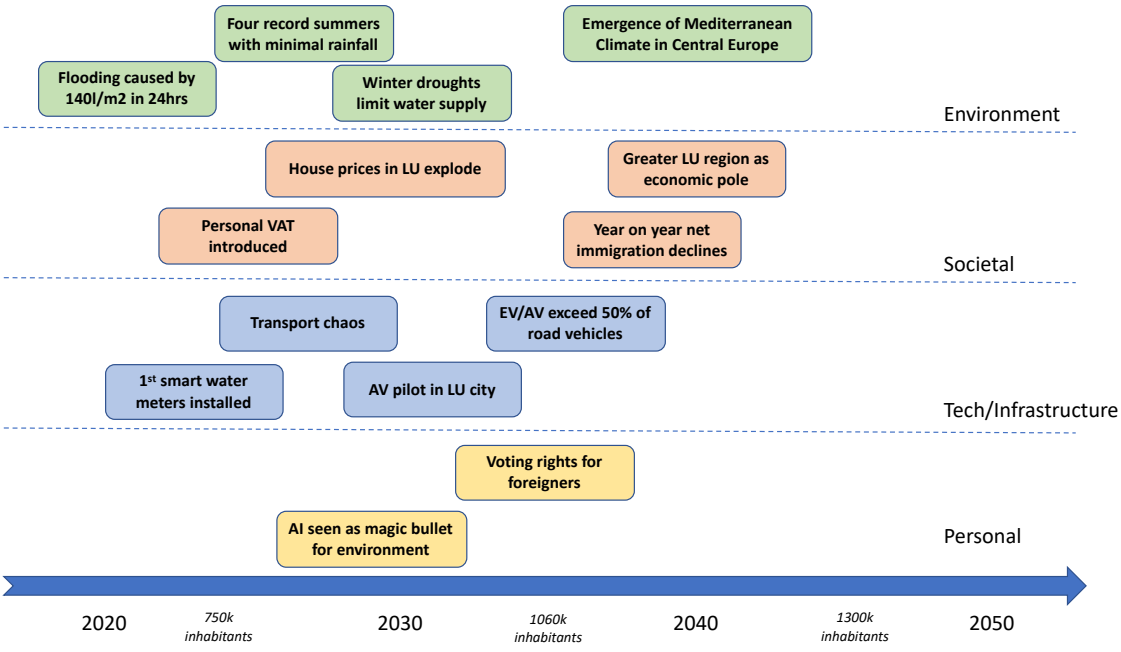

Figure 7. Timeline of key developments in the "Greater Luxembourg" Nexus 2020-2040

But the real immunity came from immigration[xli]. During the 2010's and 2020's, net immigration to the country increased from 5,000 per annum to around 34,000 per annum[xlii]. The *de facto* outcome was that new immigrants would pay for LU pensions. Immigrants were initially attracted to the Grand Duchy due to an attractive quality of life; a longstanding relative tolerance of outsiders; its

concentration of audit and regulatory services; the economics of a competitive net salary; and job opportunities.

Such a growth in population was bound to generate its own problems. Whilst economic well-being was ensured at the National level[xliii], tensions emerged around voting rights, house prices and a catastrophic transport situation. At the same time, the external nodes around the immediate Luxembourg border developed both in economic terms and in population. In effect, the greater Luxembourg region was becoming an economic network in the center of Europe and the resultant wealth insulated Luxembourg from the worst effects of any corrosion of its tax competitiveness. It also enhanced the role, reputation and influence of its government.

The changing tax situation also delivered a silver lining by contributing to a drastic reduction in the daily commute into the Grand Duchy from the surrounding nodes. True, the number of people whose employer was headquartered in Luxembourg nearly doubled to 400,000. But only half needed to travel on a daily basis[xliv]. A lower tax differential, technology and the greater (cheaper) availability of construction space in the nodes close to the border all pushed down the mass movement of people. Just as well, as that movement was suffocating the local transport infrastructure.

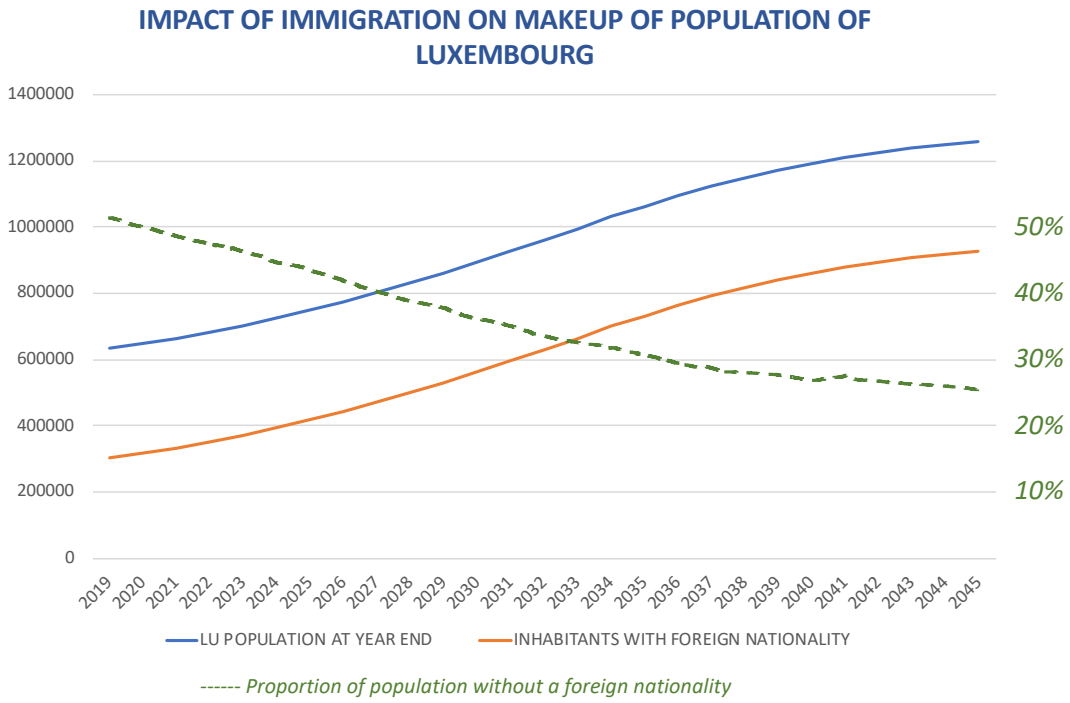

Figure 8. Population and net immigration to Luxembourg, Smart Sustainability Scenario 2019-2045[8]

Beyond the shifting tax situation, the different Universities in the Greater Luxembourg Region had developed a set of competences around the regulation, auditing and monitoring of complex circular designs. This multi-disciplinary approach required technical skills to be combined with ecosystem and behavioral knowledge. As a consequence, whilst some industry had developed around creating technical solutions as such, the real competence in the network was focused on ensuring the circularity and compliance of those solutions.

Across Europe, the existing internet infrastructure expanded to support the growing demand for smart solutions in agriculture, circular economics and the internet of things. The demands imposed by

[8] Based on 1 January 2018 data from the Luxembourg Government. Luxembourg.public.lu.

cyber-crime risks and clean AI data were much more demanding in the finance and insurance sectors, however. And large incumbents were only too happy to use these demands as a means to further reinforce their position. London, Frankfurt, Zurich, Paris and Luxembourg all expanded their internet capability to meet these demands, anxious to maintain their own pre-eminent positions. In doing so they raised the barrier for new entrants, but they also contributed to a reduction in overall resilience of the financial infrastructure. As we all saw during the derivatives crisis of 2035, collapse of one key link has a chain reaction across the entire sector.

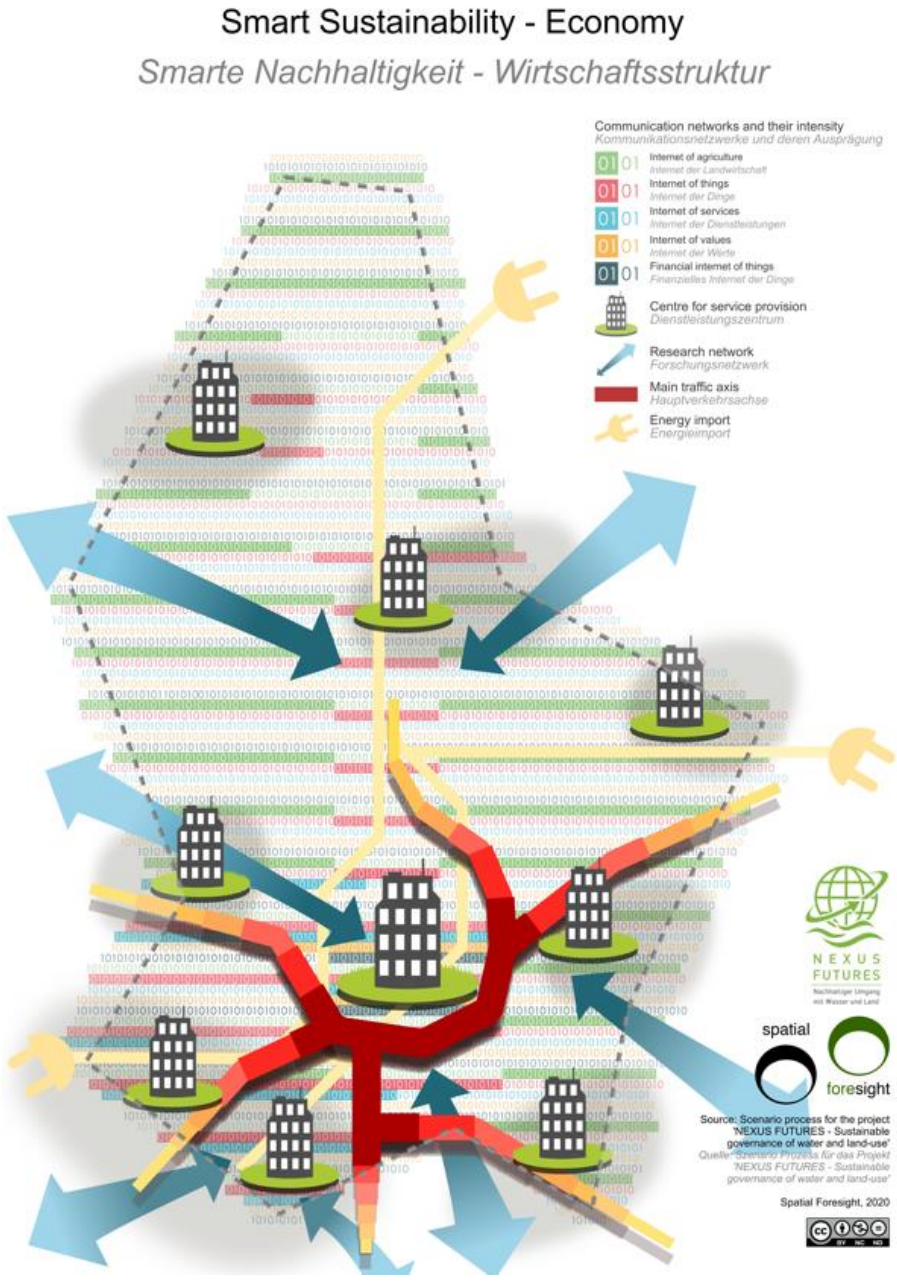

Figure 9. Economic overview for Smart Sustainability. Courtesy of Spatial Foresight.

The upshot of these different forces was that economics trumped both local values and the environment. GDP growth for the Greater Luxembourg region as a whole was 3% on average during the period[xlv]. There were some nuances. Luxembourg itself grew at 2,5% whereas the more populous outer nodes grew at a faster rate, namely 3,2%. This differential was caused, in part, by faster

population growth in the outer nodes. The main driver however has been the need for higher levels of infrastructure investment (IT, cyber-resilience, buildings, water, waste treatment, local energy, mobility…) compared to the Grand Duchy itself.

Productivity as measured by GDP per capita in Luxembourg remained steady at around €100k up to 2045[xlvi]. The surrounding region saw some important increases consistent with its emergence as an economic network. With small variations between the different countries, GDP per capita in the settlements encircling Luxembourg surged to just over €55k per capita, up from €41-45k in the late 2010s[9].

Initially, many environmentalists were frustrated at the so-called rebound effect[xlvii]. Basically, when clean energy prices declined, people simply felt free to consume more energy. Thankfully however, the eventual comprehensiveness of the different measures finally reduced the rebound effect to a marginal impact. As to the initially severe increase in unemployment caused by AI and autonomous vehicles, this was gradually eroded by an aging population leaving the workforce and new opportunities opening up in the social care, tourism and hotel/restaurant sectors. As a result, the working week for full-time employment has decreased only slightly across the Region from 40,3 hours in 2016 to 39,5 in 2045[xlviii].

Increasing construction density of the region's cities and towns could not hide the gradual encroachment into neighboring green belt land. Immigrants were eventually given full voting rights around 2035. Paradoxically, this immediately, and directly, led to attempts to slow down new immigration into the Grand Duchy if not the greater region. Paying pensions was less important to the new voting class compared to the quality of life that had attracted them to Luxembourg in the first place.

The new political dynamic accelerated housing construction and put the brakes on what had become an over generous indexation of pensions.

Challenge Box 4. Population change is only positive?

For the Greater Luxembourg Region, the Smart Sustainability scenario sees largely positive impacts from immigration. The population mix of Luxembourg is radically transformed and most immigrants are finally given the right to vote. All is seemingly well in the Grand Duchy.

Given recent history, the plausibility that events unfold in this way seems reasonable enough. But what challenges need to be overcome? The decisive shift towards a country where the majority of inhabitants are immigrants changes much more than a few statistics. The very source code of society is rewritten - education, lifestyle, culture and much, much more.

The challenge for Luxembourg is to navigate these changes in such a way that the outcome is positive for all. Can it?

[9] Productivity is measured here as GDP per capita. This common measurement avoids making any assumptions about working time and employment levels. 2018 data is sourced from the OECD (Reference 46). Constant values in USD - 2010 prices at purchasing power parity. 1,1 EUR = 1 USD.

By the end of 2045, the greater Luxembourg region was a wealthy economic and regulatory network at the center of Europe. And this wealth enabled complex, hi-tech, expensive, some would say necessary, cross-border infrastructure projects to be installed around water, transport, energy and recycling. But this wealth came at a price.

Inequity within Luxembourg has grown, and its consequences are visible everywhere. Across the Greater Luxembourg region, energy and resource efficient affordable housing for migrants and the young have been built. But they are located mostly on unattractive, brownfield sites reinforcing poverty ghettos. Water consumption is micromanaged, but only the rich can afford the additional tariffs and expensive technologies. And the more recent squeeze on pensioners has forced many to move away from the Duchy to more affordable housing.

Luxembourg is now more diverse but less cohesive.

The environment has taken a serious knock and water resources are on hi-tech life support. As to biodiversity within the Region – flora and fauna are in serious retreat. In fact, the only wild mammals visible outside certain sanctuaries are mouse sized.

3.2. REGULATION IN AND AROUND LUXEMBOURG

In terms of property ownership, the basic rights accorded by the 1868 Constitution (Articles 16 and 17) have remained unchanged in the past 30 years. Property owners retain strong protections against expropriation by the State for any but the most compelling of reasons. In terms of environmental legislation, the main emphasis has been to uphold the legal (*Res Nullis*[10]) and economic rationale of property ownership whilst occasionally imposing (technocratic) restrictions on how it can be exploited.

Generally speaking, Luxembourg society has embraced the Europe-wide regulatory changes that have been so characteristic of recent decades – not least because many of them have emerged from the institutions located so prominently in the Grand Duchy.

The increasing complexity of environmental and smart-related regulation has given rise to a much-needed expansion of the audit and compliance sectors. This expansion readily, and in a very timely way, filled the growing employment gaps caused by the expansion of AI into the financial and legal sectors.

As a result, the Greater Luxembourg Region has emerged as a center of regulatory expertise. Consequently, local authorities across the Region have seized on this competence as a means to be a *"reference algorithm"* for piloting green change in a European framework.

3.3. ENERGY IN LUXEMBOURG

Like many countries, Luxembourg has invested heavily in local energy supply. Wind and sun energy dominate the local mix with geothermal contributing relatively little. The main issue for geothermal has been around damage to local water aquifers. Wind has also been held back around planning permission issues. On the other hand, technical fixes in solar (roof tiles, shared use with transport infrastructures …) has accelerated the deployment of this particular energy source. The emergence of a clean and cheap hydrogen economy around the North Sea has encouraged Luxembourg to cut back a little on its initial plans to be 75% energy self-sufficient[xlix]. Overall, Luxembourg now produces, on average, 60% of its own electricity supply.

[10] *Res Nullis* derives from Latin Law where items (*Res*) are considered to be ownerless until acquired through means of *occupatio*. A bird in the forest is therefore ownerless whereas a bird in the hand is property. Source. Wikipedia.

Challenge Box 5. Nexus decision making in Luxembourg
Luxembourg invests heavily and continuously into Nexus sustainability in the Smart Sustainability scenario. In many ways, this scenario paints a picture of the poster-boy Nation State. Whilst plausible, this is still terabytes away from today's reality. So which decision-making criteria would lead to such investment? Would investments in the Nexus only be made if they were both sustainable and economically viable? Is there space for economically sub-optimal investment in the Nexus? And at which point, and on which criteria, would Luxembourg deviate from sustainability principles e.g. on energy, food, construction materials or water?

Local, disseminated SMART battery storage has been gradually installed across private homes, businesses and the mobility sector. This disperse capacity deals with a significant proportion of the daily and weekly peaks, but seasonal peaks in the winter months require large volume energy imports.

The remaining 40% of total electricity supply comes from surrounding countries. This is usually because their energy storage (e.g. hydrogen) facilities have been constructed on a larger scale. But also, it is simply cheaper to pay others to manage the complexity of peak demand, intermittency management and renewable diversity.

3.4. LAND USE IN THE GREATER LUXEMBOURG NETWORK

The narrative of land use in the Greater Luxembourg network has primarily been defined in recent decades by the tension between the forces of population growth driven by immigration to the region and the need to protect the local ecosystems.

The Luxembourg State first started actively attracting migrants in the early 2000's through an attractive taxation framework. That in turn attracted economic migration from within France, Germany and Belgium to the greater Luxembourg region. The dynamic of the early part of the 21st century was one of economic growth, increasing population and a mass daily commute across the borders. During the 2010s, the Grand Duchy enjoyed an average of 2,6% growth and by 2020 had a population of some 700,000 with nearly 200,000 enduring the daily commute.

By the mid 21st century, the region remains an economic outlier inside Europe although the various taxation frameworks that are applicable have changed considerably. The greater Luxembourg network has seen sustained growth of 3% driven primarily by productivity from automation and the Grand Duchy's population is now nearly double at 1,3 million. The daily commute is however sharply down. Developments in tax, mobility infrastructure and automation have all plugged-in to this trend.

And if that was all, then the region would have developed into a vast sub-urban sprawl, after all there was plenty of land available to accommodate the higher population[l], but these were not the only forces at play.

The global scarcity of viable agricultural land and the drive to capture more carbon through forestry forced nation state planners to be much stricter on urban development. Town and city density increased throughout Europe over the past two decades and the Region was no exception. There was however some relief from the lower demand for transport and logistical infrastructure. In 2036, Belgium became the last of the four countries to sharply reduce parking space requirements for new

housing and office developments. Lower car ownership and fleets of cheap autonomous, electric vehicles empowered councils to demand that city dwellers mostly forgo their personal four-wheel privileges. Luxembourg city in particular, saw developers rush in and expand these breaches to transform the under-utilized mobility spaces into other uses.

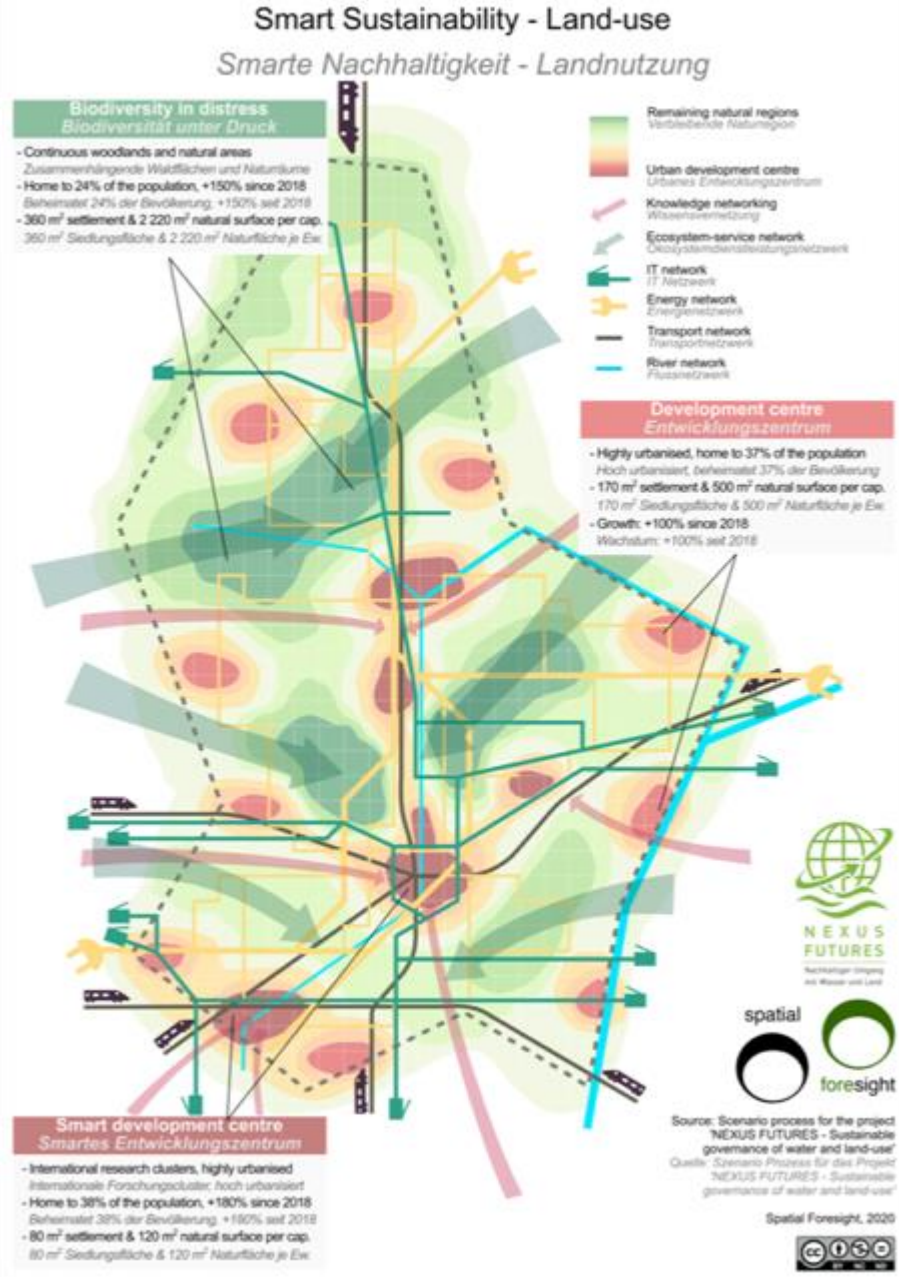

Figure 10. Spatial planning overview for Smart Sustainability. Courtesy of Spatial Foresight.

This planning offensive was extremely effective in areas where population growth, mostly migrants, was strongest. As a result, the nine[11] main population centers in the region remained largely within their boundaries despite increasing their populations. The region even won several international architects' competitions as companies reimagined building methods and found new ways to reduce the logistical loads that surrounded construction.

[11] The nine population centers in the region referred to here are Luxembourg city, Esch-sur-Alzette, Thionville, Longwy, Arlon, Trier, Bastogne, Echternach and the Diekirch-Mersch corridor.

But resistance was ferocious among those established, property owning residents in the wealthier outskirts.

These residents had been obliged, albeit with some financial support, to retrofit their houses in order to make them smart, energy efficient, water efficient and greener. They had been submitted to a raft of rules, regulations and intrusive monitoring. And so, each time any aspect of their freedom to move was challenged, for example to reclaim land for agriculture or forestry, their guerilla-style resistance was total … and understandable. After all, they had spent their hard-earned wealth on smart, green technology, why should they give up even one minor road? As a result, construction in the countryside, if anything, expanded slightly over the past 25 years through a wide-range of "exceptional" planning permissions.

The region also suffered from fragmented governance among its four Nation States. Physical infrastructure pretty much stopped at the border. People, technology, population, capital, companies, wealth and land ownership on the other hand could all move freely. The outcome was that infrastructure continued to be duplicated with significant human bandwidth, processing time and resources being spent on compatibility and data sharing. And whilst many Luxembourg companies benefitted from the additional contracts and work, they did so at the cost of their home market being opened up to greater competition, especially from German suppliers.

Land ownership in the main population centers was an especially difficult challenge in the early 2020s. Land grab by large international and private investors was commonplace. Housing costs exploded artificially. The main driver was the fact that land ownership had shifted away from being a local mix of private and public towards a foreign mix that was predominantly private and less transparent. And although these new owners were more willing to accept stringent building regulations and invest in innovative uses of land, the downside impact on access to affordable housing was simply too great.

Two fundamental lessons were learned and gradually implemented over the past two decades.

Firstly, public authorities should not concede land by selling it, but should rather sell the use of land. This principle initially applied to land for industry and infrastructure such as data centers, but it then expanded to mainstream housing construction.

Secondly, the firewall of secrecy that surrounded land ownership was lifted. Inspired by efforts in London, Paris and Berlin the Grand Duchy used the newly acquired knowledge to make sharper distinctions between those who were investing in Luxembourg and those who were speculating. In short, profits from increasing property values could no longer be expatriated so easily and so quickly.

The net outcome of all of this is that land use in the Grand Duchy has barely changed over the past decades. In 2020, 1 acre in 11 was set aside for use by buildings and industry. Today, that is 1 in 10. The density of construction in the main population areas is sharply up. But so too is the density and extent of agriculture and forestry. The main losers have been sprawling industrial estates, shopping malls, parking infrastructures and Siedlung developments outside towns and villages.

3.5. WATER IN THE GREATER LUXEMBOURG REGION

Towards the end of the 2010's, average Luxembourg water production was 7,600m3 per hour compared to an average demand of 5,200m3 per hour. Storage capacity to absorb seasonal impacts was an adequate 250,000m3.

During the next 25 years, this equation underwent some fairly drastic changes.

At first, everything appeared to be under control, despite occasional water shortages due to reduced ground water levels.

At the central level, (i.e. without much involvement of the general population), potential water shortages were overcome throughout the 2020s. The main contribution (nearly 90%) came from the new SEBES plant finished in 2022. The remaining 10% came from new water sources. In total, this delivered an additional 41,000 m3/day. Throughout the same decade, incremental technological improvements with regards to recycling of water in the household were introduced into new housing estate projects. Smart meters[li], low water-use showerheads, grey water toilets and technology-based water recycling were all mandated for new build. These measures were complemented by parallel measures for existing buildings. Between 2020 and 2030, the widespread installation of smart water meters had improved public awareness of their water consumption and reduced it accordingly. All in all, this portfolio of measures was designed to ensure that the influx of people to Luxembourg was matched by water savings or extra production.

SMART SUSTAINABILITY IN THE GREATER LUXEMBOURG REGION

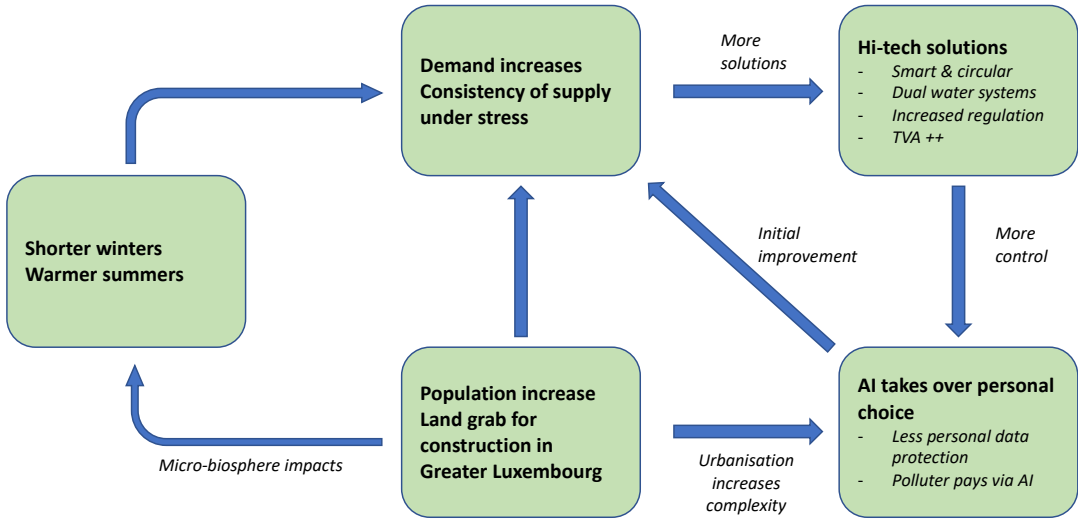

Figure 11. AI gradually takes over personal choice in the area of water – Local model for Luxembourg

Sadly, incremental change cannot compete with disruption.

Throughout the 2020s, the world of water in the Greater Luxembourg region was increasingly being dominated by regional climate change. It was a change that gradually brought a Mediterranean climate into the bastions of Central Europe. And whilst the change led to milder winters and warmer summers, the hydrological impact was much more serious, and (initially) less visible. The cold reality was that, notwithstanding a faster than expected transition to a renewable energy economy, the accumulated legacy of nearly 300 years of greenhouse gases being steadily pumped into the

atmosphere was taking its toll. [12] For the landlocked Greater Luxembourg region, the changing seasons and growing population had been a terrible burden on the water supply/demand balance.

Climate change alone would have been disruptive enough on its own to upset the water supply-demand equation in the Grand Duchy. But there was more. Accelerated growth in population; changes to food culture (eating out and take away food); a growing influx of daily visitors and an AI driven boost in the number of data centers in the region. These changes combined forces with the the non-trivial fact that, historically, a wide range of industrial consumers had switched, for cost reasons, from electrical cooling to water cooling thereby aggravating seasonal consumption. As a direct result, experience showed that, especially when the temperature exceeded 30 degrees, water consumption increased significantly.

The net result of all these changes was that total water consumption in the Grand Duchy shot up from an average 120 million liters per day in 2012 to 174 million by 2030 leaving precious little room, for the usual summer increase.

On the supply side, there was not much that could be done to improve the situation. In the subsequent 25 years, dryer winters had a negative impact on water availability but so too did the emergence of a shorter hydrological winter as plants and trees curtailed their hibernation periods due to a more Mediterranean climate. Dry summers further delayed the start of rebuilding ground water levels during what was now a shorter winter. As if all of these factors were not bad enough, steady winter rains made way for large and sudden downpours. The net result was that local water aquifers regularly failed to get adequately replenished.

Challenge Box 6. The Luxembourg water challenge

The Smart Sustainability scenario sees Luxembourg, mainly through a series of technical and regulatory fixes, navigate its way through some very serious water scarcity challenges.

But would rational, technocratic, decision making dominate the debate? Would the local population remain patient in the face of such a sustained water crisis? Would industry consumers anticipate Nexus 2.0. or would they legally insist on the water rights they have acquired?

The vital storage capacity of the Stausee has continued to operate in the past 25 years. But with shortening winters and warmer summers, the initial policy response was to expand storage capacity. Incentives were offered to industrial and private users alike to establish rain collection and storage facilities. Attempts to extract more surface water stumbled on basic hydrological realities. The temperature of the Mosel in the ever longer summer was around 27 degrees whereas the maximum safe, (i.e. for human health), temperature for the water network is 20 degrees. And although the Grand Duchy's engineers briefly considered mass cooling, notwithstanding cheap, (but intermittent), renewable energy, it was simply a non-starter.

A more promising approach to augment the regional water supply was to transfer abundant, surplus water from the sparsely populated areas of Southern Belgium. The technical challenge was that this water supply is geographically disperse and would have required major infrastructure to collect and distribute. Despite interest from Germany, France and Luxembourg however the Belgium government was unable (or unwilling) to back a project that would potentially, seriously disrupt the ecosystem of a

[12] This scenario uses the IPCC set of global climate change scenarios. SSP2 from this set delivers 4,5 to 6 W/m2 of radiative forcing. 6 W/m2 is equivalent to 3 degrees (possibly more) global warming by 2100. In the Smart Growth world, improvements in sustainable energy and recycling are more than offset by economic growth i.e. greater global consumption.

valuable tourism region. In any case, the pitiful state of many trees and vast forests were the dominant ecological agenda item for the countries concerned. Huge replanting programs were taking place at the same time[lii], and there was simply no appetite for yet another major surgical intervention.

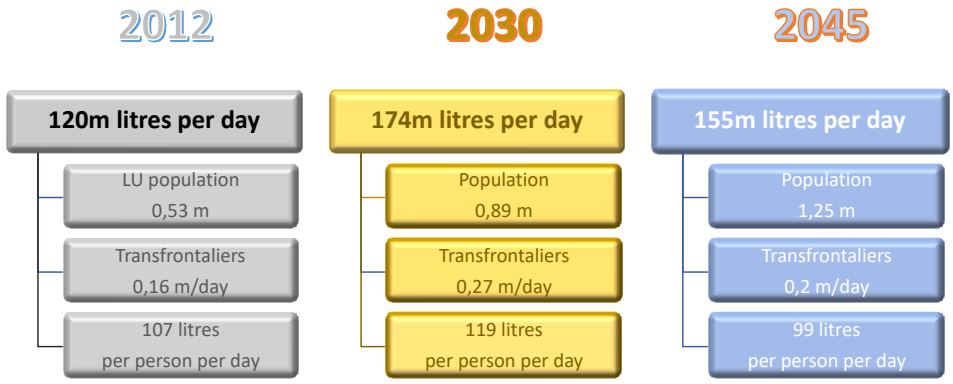

Figure 12. Drinking water in Luxembourg 2012-2045[13].

The reluctant conclusion was that all the wealth and technology combined could not raise water production in any significant way in or around the Greater Luxembourg Network. Water output had reached a hard limit. Something had to give on the demand side – but it didn't until it was almost too late.

Towards the end of the 2020s, twin hydrological disasters crept up slowly but steadily on the region. A series of warm and dry summers were followed by a series of relatively short winters. These winters experienced precious little steady rain, rather near tropical downpours were the norm. The drastic impact on ground water levels and local aquifers drew dire warnings from water engineers. Warnings that either went unheeded, or received an inadequate technical patch, against the backdrop of a turbulent political environment. And all the while, immigration continued apace and the local population (and demand) just kept on growing.

The first visible signal that something was seriously wrong showed up in the form of unseasonably low levels in the Syr and Obersauer. The Schiessentümpel, symbol and emotional trademark of Luxembourg along the Schwarze Ernz (a tributary of the Sauer), was reduced from a glorious cascade of life to a sad trickle, its three liquid fingers barely visible against the underlying rocks.

This highly emotive impact of climate change, and failure of an over complex governance model, was a major trigger for a change in social attitudes to water. Of course, the subsequent prolonged and widespread water rationing, (strictly enforced by smart water meters that had been so helpfully installed earlier), hammered home the point and ensured that this particular climate disaster was not going to be easily forgotten.

From that moment on, Luxembourg joined countless of other communities across the world in appreciating the deeper value of water. The Grand Duchy's response was predictably technocratic – invest in yet more technology and sharpen further the rules and regulations.

[13] Extraction per person includes Transfrontaliers. (2012 overall water extraction data is from Eist Wasser, 2013, Administration de la gestion de l'eau. 2012 population and Transfrontaliers data. See also references 46,47)

It was the data centers that generated the greatest popular anger when water rationing was introduced. In the 2010s, 67% of all water was consumed by households. That figure had been reduced to 61% by 2030, mostly due to the behavior of industrial consumers, including data centers. Their long-standing licensing arrangements, a pre-condition for them to come to Luxembourg in the first place, meant that water rationing did not apply to them and that was neither forgiven, nor forgotten. Especially at the next elections.

Water rationing had worked but the population was growing. Politicians, and society at large, had finally accepted that increasing supply was a non-starter. The only solution (technical of course) was to adopt state of the art practice in terms of recycling and impose radical pricing policies that differentiated water consumption using transaction taxation.

From the point of view of local society, there was really nothing unusual or controversial in the 2031 Decree (see Figure 12 below). A problem had occurred and a (technocratic) solution was required. And it was not as if Luxembourg was in an unusual situation in Central Europe. Other, more densely populated, cities and regions had been obliged to take much more radical measures. Some, for example, had demanded the retrofit of Dual Water Cycles in all hotels, offices and restaurants. In point of fact, throughout Europe water was increasingly being seen as a precious resource whose use and re-use had to be measured, and controlled, microscopically.

Indeed, it was this general context that forced the owners of the big data centers, including those in Luxembourg, to withdraw any threat to move elsewhere. Instead they engaged in rational decision making, stayed put, consolidated and retrofitted their cooling systems away from freshwater extraction.

Target	Main Water Management Measures
Leakage	Previous leakage rates of 5-20% are further reduced using an extensive network of sensors linked to AI-based machine learning. Leaks are detected quicker and centrally. Leakage repair companies authorized to have immediate, unrestricted access to any land or property.
Dual water cycles	All new construction, from 1 January 2037, must have dual water cycles that separate grey and drinking water. Both cycles must have extensive sensor networks with AI control based on water consumption purpose.
Storage	Further incentives for local water capture and storage capacity.
Industry	Complex mix of incentives and taxes aimed at forcing closed circuit water cooling and/or encouraging alternative (non-water based) cooling systems. After a 5-year transition period, non-compliance will lead to water rationing during periods of shortage.
Consumption tax	Individual water consumption is tracked for the purposes of TVA. Water consumption is measured at household level, work and restaurants. Higher TVA rates kick in above 100 liters per person per day and for all visitors.
Agriculture/forestry	Priority given to sustainable agriculture. Higher (TVA) tax brackets apply to dairy and meat farming. Incentives for grey water management.

Figure 13. Summary of 2031 Luxembourg Water Management Decree.

But the kind of changes laid out in the 2031 Decree would take 3-7 years implement and show results. In the meantime, limitations on personal water use continued.

In the 10 years that have passed since the 2031 Decree, progress has been steady but very slow. The continued increase in Luxembourg's population, albeit at a slower rate than the early 2030s, has been partially offset by reductions in the daily commute across the border. These reductions have been driven in part by a lower overall taxation differential and significant improvements in virtual communication technology. But it should not be overlooked that many expanding companies now have offices both in Luxembourg and in one of the neighboring countries.

The priority to sustainable farming delivered the bonus (+185,000 m3/day in 2035) that additional local water sources became once again available. Pesticides/herbicides/fungicides not only declined in use, their removal by activated carbon and/or ozone was mandated. Drinking water zones were able to expand during the period and micropollutant levels declined accordingly. Nevertheless, the reality of an aging population consuming more and more, novel drugs meant that new micropollutant compounds were being found that needed treatment. Some forms of this treated water were made available for farming of crops that were not sensitive to micropollutants – a decision that was fiercely opposed by the growing organic farming movement in the region. Later on, there was a trend during the period to inject treated wastewater into aquafers.

Despite politically motivated, generous transition arrangements, the new regulations initially slowed down construction as designers and developers rushed to catch up. The Central European market was booming for hi-tech 'circular' housing solutions and the Luxembourg situation fitted well into the general pattern – and they had more money. Luxembourg was therefore able to swiftly expand its construction both upwards and outwards to meet its population needs. The focus has been to increase the living density of the main habitation areas and to stay way – as much as possible – from the main nature and water catchment areas.

Cross-border tensions continue as construction developments in the Greater Luxembourg region frequently interact in unforeseen ways with those in the Grand Duchy itself. AI and sophisticated local citizens' science are revealing these tensions at a faster pace, but bi-lateral and multi-lateral co-operation around the main river basins is slow and inefficient.

In conclusion, expensive and sophisticated technology has managed to stretch out available water resources without a fundamental change in human consumption and behavior. The corresponding sharp rise in the cost of water has helped, not least because it has enabled certain technologies to be cost-effective. But the situation is precarious. All the while, changing weather patterns continue to conspire against human ingenuity.

4. WHAT IS UNATTENDED TO? WHO IS LEFT BEHIND?

By 2045, Europe was scarred by the aftermath of two decades of an intense fourth industrial revolution. People have been forced out of their jobs on a large scale and State-sponsored re-skilling efforts have, at best, delivered patchwork results. And whilst life-long education is widely seen as the only enduring solution, the return on educational investment has sharply deteriorated. In the 2020s, a 6-year study would be a sound basis for a decades long career, in the 2040s such a study was widely seen as uneconomic and a wasteful indulgence.

And whereas those with the ability and wherewithal to re-educate themselves throughout their lifetimes have at least some grounds for optimism; the same cannot be said of the millions of former workers in the mobility, administrative and legal sectors. Their concerns are echoed by populist parties and unions. The former seizing on every opportunity to stoke fear about unemployment and the subsequent rise in social security costs and crime levels. The latter advocating protectionist measures and enthusiastically seizing on every technical hitch, data breach and AI judgement error.

Legal activism against some of the worst excesses of AI has actually helped the economic transition to progress. Courts, and regulators, have approved access to AI algorithms, source code and key data sets to allow third parties to identify flaws and to better allocate responsibility. More generally,

the economic and regulatory environmental forces lined up against the concerns of those who are unable to keep up are simply too powerful.

For Europe at least, there have been a number of mitigating factors that have lightened the blow caused by these disruptive changes. The ability of the Nation State to recover greater levels of income from major digital companies and the wealthy has injected much needed financial support to otherwise fragile national budgets. Another mitigating factor was the combination of an aging population combined with stringent anti-immigration regulations.

This combination of factors meant that employers, at least in some sectors, found it difficult to recruit and retain new staff thereby encouraging a gradual aging of the workforce. Furthermore, new employment opportunities emerged in the hospitality, social support and regulatory sectors. But perhaps the most important mitigating factor of all was the encouraging levels of economic growth across the continent as productivity improved and global trade expanded.

Nevertheless, a gap between the ongoing-educated and those left behind is growing and it ferments considerable unrest and disillusion. This translates into regular, occasionally violent, attacks on all things *"robotic"*. There is wide-spread vandalism of remote monitoring devices, speed cameras, unmanned AVs and 8G infrastructure. But there is also targeting, via social media, of those involved in the design, selling and operation of this impersonal and threatening *"robotic"* world.

For years, the storm clouds have been clearly gathering around the resultant loss of social cohesion. Governments looked in vain for better taxation models and improved re-skilling programs. They were generally successful on the tax front. They had to be given the struggle to pay for a creaking social security net. With the benefit of hindsight, they were utterly hopeless on the re-skilling front.

For the global eco-system, economic growth has trumped technological innovation. The outlook is now dire – 4 degrees by 2100. True, there has been a huge reduction in **new** CO2 and other harmful emissions. But neither this trend nor the improvements in circular business models have been unable to prevent ongoing damage caused by the inheritance of the past. In short, there has been a continued accumulation in the global stock of greenhouse gases during the transition period as well as a growing demand on declining amounts of green space.

Not surprisingly therefore, scientists have had a frustrating time. Their warnings have been systematically ignored by politicians, businessmen and society who all put their faith in the magic bullet of technology. And whilst it is true that technology has delivered, it also served as a convenient excuse to continue business as usual in the meantime. In retrospect, the promise of technology encouraged society to change nothing in its search for economic, consumer wealth. Judging by the climate forecasts for the next 50 years, there will be a very heavy price to pay.

This onslaught of technology, especially in Central Europe, has further distanced society from the reality of an ecosystem.

This is a society that is utterly dependent on the machine, and much less resilient. Human and agricultural demand for green space has increased despite a reduction in demand from mobility and an increase in city density. Climate change and natural catastrophes in areas of the world that were previously important food producers have led to increasing levels of agricultural land use. At the same time, an aging population has driven upwards the number of single person households, energy consumption and the amount of land dedicated to housing.

5. WHAT IS THE OUTLOOK FOR THIS WORLD?

Society in 2045 feels very ambiguous and anxious.

This is a society that has successfully delivered one of the greatest transitions in the history of mankind. A decisive shift has been made away from fossil addiction towards carbon neutrality. The energy transition is a fact. Climate change challenges around water and the use of land have been confronted and overcome. Society has handed over much personal freedom in return for a cleaner world and greater wealth. So much has been invested, regulated, mitigated and achieved.

Economically things are good. In the greater Luxembourg region, they are very good. Lifestyle might be microscopically controlled, but most people are comfortable with that. The convienience, and the lower cost, has made most individuals *"comfortably numb".*

And yet, there has been a price. On the social side, across the globe, countless individuals and communities have been left to pick up the pieces of a livelihood removed by AI and AV. Many more now live with the bitter tragedy of having lived a life that they now see was spent undermining the future of their progeny. Some are angry, very angry.

For decades, the promise of *"jam tomorrow"* empowered the convenience of business as usual. And now the bill is being processed by planet Earth. There is no longer time for payment on credit. Accumulated stocks of carbon have never been more dangerous. The outlook is dreadful – 4-degrees warmer than 1900 by 2100. The following decades will see probably even higher temperature growth before, maybe, falling back to 4-degrees. And all around the planet are the visible eco-system consequences of the 3-degree journey to this point.

A salutary lesson in economics

This is the story of the professor who wanted to explain smart growth to her students. She took a glass container, filled it to the brim with pebbles and asked the students whether they thought that the container was full. As the students answered in the affirmative, she then proceeded to mix gravel among the pebbles filling the gaps between the stones. The professor then repeated the question whether the glass was full. Again, the students answered positively. This time she took some sand and added it to the pebbles and the gravel. The students all agreed. Now the glass was surely full. Hereupon the professor took a jar with water and poured the water onto the mix of pebbles, gravel and sand.

The Professor placed the glass outside on the windowsill and returned to teaching basic economic theory. Just as the students were about to leave, she reached out and placed the glass on the table. It was freezing outside and the glass was cracked and broken.

The real lesson was simple. In a constrained environment, there is such a thing as too much growth[14].

The question on everyone's lips is *"are we too late?".*

Generational tensions are everywhere to see. Younger generations who largely disengaged from the political process over the past decades are awakening. They have misplaced their trust in technology

[14] Thanks to Edgard Arend for this inspirational story.

and business as usual. The awakening is a rude one. There is a simmering anger towards the massed ranks of older generations. But above all, there is a sense of urgency.

Something must be done to reduce the accumulated damage of 300 years of industrialization.

Deep adaptation is one route – a radical change in human behavior. But that is an anathema to the countless human beings across the planet who have successfully delivered a carbon neutral economy. Large scale, net reforestation is popular and is already underway, but many scientists are suggesting that mankind might have left it too late. Technical fixes exist to capture CO2 and even to release oxygen back into the air. But the technology is not yet on a scale that works and Nation States are still bickering as to who should pay. And finally, the international community is simply exhausted dealing with one eco-system crisis after another.

Life in Luxembourg is tranquil. Water is managed. The economy functions and social welfare for the elderly is well in hand. Land use by mankind is up, but only slightly. The air is a lot cleaner and healthier. The roads are quieter. The forests of central Europe have been renewed but the underlying flora and fauna have yet to recover.

Luxembourg is an integral part of a bigger global village that has achieved the astonishing and, yet, must now urgently do so much more or it will all have been for nothing.

KEY CHALLENGES

THE GLOBAL CONTEXT

- *How will society deal with the disappointment of having the overall environmental benefits delivered by a smart circular economy largely offset by economic growth and inequality?*
- *How will democracy adapt to a world where artificial intelligence is applied to circular economics, thereby restricting freedom and personal choice? Will society remain "comfortably numb"?*
- *How will an aging society deal with the end of retirement coinciding with mass layoffs emerging across multiple sectors?*

THE LOCAL TRANSACTIONAL CONTEXT

- *Can Luxembourg make a full success out of the deep-seated changes underway in the population mix of Luxembourg?*
- *What decision making elements will cause Luxembourg to invest in Nexus sustainability? Which elements will push the Grand Duchy to rely on its neighbors?*
- *Can Luxembourg embrace the dynamics of change required to have a sustainable water ecosystem?*

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xxix The long-term impacts of historical immigration policy will lead to a very different mix in the European and Luxembourg workforce in this world. https://www.thelocal.fr/20171201/how-frances-muslim-population-will-grow-in-the-future

xxx The struggle for Nation States in terms of taxation revenue has been visible for a number of years. The digital economy in particular is a target of reform as it is widely seen to be underpaying in taxation. For example, "France unveils new tax for global internet giants" by B. Cambreleng et al., Yahoo, 6 March 2019. It is a sensitive subject as shown by this quote from Donald Trump in reaction to the French initiative at the NATO summit on 3 December 2019 - "I'm not going to let people take advantage of American companies," the president said of France's digital tax policy. "If anyone is going to take advantage of American companies, it's going to be us. It's not going to be France."

xxxi For some digital companies, the tax gap throws up unusual observations. https://www.theinquirer.net/inquirer/news/3070503/google-now-pays-more-in-eu-fines-than-it-does-in-taxes

xxxii http://www.oecd.org/tax/beps/public-consultation-document-addressing-the-tax-challenges-of-the-digitalisation-of-the-economy.pdf

xxxiii Japan is a country whose aging demographics are far ahead of those in Europe and China. The cost of an aging population can sometimes throw up surprising consequences. "Why some Japanese pensioners want to go to jail." BBC 31 January 2019. See Japanese Ministry of Justice official statistics and https://www.bbc.com/news/stories-47033704.

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xxxvii https://ec.europa.eu/eurostat/statistics-explained/index.php/Tax_revenue_statistics#In_2017.2C_tax_revenue_in_absolute_terms_increased_in_27_EU_Member_States

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xxxix “Gilets jaunes protesters ‘destroy over half of speed cameras’ in France.” Independent. 10 January 2019. www.independent.co.uk/news/world/europe/gilets-jaunes-france-speed-cameras-yellow-vest-destroy-vandal-limit-emmanuel-macron-a8720651.html%3famp

xl Collaborative Conceptual Systems Mapping and its potential for transformative dialogues. Dr. Ariane König et al. February 2019. The Smart Sustainability scenario is notably absent of such transformative dialogues.

xli https://www.troisiemerevolutionindustrielle.lu/wp-content/uploads/2016/11/CC-brochure-3e-revolution-FR.pdf

xlii To put this annual immigration flow in context, see http://luxembourg.public.lu/en/le-grand-duche-se-presente/population/index.html. Population of Luxembourg on 1 January 2018 and the split between Luxembourgers and those with a foreign nationality. 602,005 in total. 313,042 Luxembourgers and 288,963 with a foreign nationality.

xliii Die räumliche Dimension der Strategie zur 3. Industriellen Revolution für Luxembourg. 2017-131 MDDI Spatial Rifkin.

xliv Luxembourg has a proportionally very high number of people who work in Luxembourg and who live in a different country. These so-called “Transfrontaliers” numbered 150,100 in 2010. https://statistiques.public.lu/catalogue-publications/luxembourg/2012/PDF-04-12.pdf. By the end of 2017, it had increased to 183,548 per day. Up 6,961 since 2016. https://www.wort.lu/fr/luxembourg/de-plus-en-plus-de-frontaliers-travaillent-au-luxembourg-5aaa6323c1097cee25b84f63

xlv For comparison. Real GDP growth in Luxembourg was 2,56% per annum between 2011 and 2018 . OECD country specific profile. Key tables as of 22 July 2019. GDP per capita grew from USD 91,814 in 2011 to USD 110,906 in 2018 or an average annual increase of 2,60%.

xlvi The OECD stats website contains historical data on different productivity measures. German, French and Belgian data is not broken down to level of the regions around Luxembourg. Averages have therefore been used to illustrate the change over the period. 1.1 EUR to 1 USD. Productivity, GDP per capita, https://stats.oecd.org/Index.aspx?DataSetCode=PDB_LV.

xlvii Rebound levels are higher when energy conservation measures are deployed. This offsets the impact of the measures to a certain extent. https://www.sciencedirect.com/science/article/pii/S0301421513011233.

xlviii Working hours in Europe. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20180125-1

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l Landnutzung in Luxembourg 2050. 2018-152 MDDI land use scenarios.

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