Luxembourg in Transition

SOIL & PEOPLE

2001
Lola
51N4E
Systematica
Endeavour
TUK
ETHZ
Transsolar
Yellow Ball
OFC
Gregor Waltersdorfer

Stage 1 Dossier

December 2020

Contents

1.1 Executive Summary

With a concentration on lifestyle changes, land use change and regenerative agricultural practices, we have put forward a quantifiable decarbonisation trajectory for the functional territory of Luxembourg. We have adopted the European Commission's 1.5 LIFE scenario [1] as our baseline and have presented the tools and metrics by which we can exceed its ambitious goals within the sector of LULUCF (Land Use, Land Use Change and Forestry). In addition, we have outlined an overarching preliminary vision for reorganising communities and resources, that is rooted in a bioregional outlook.
By facilitating a transborder, multiscalar conversation among neighborhoods and nations we intend to embolden local actions that have global impacts. Adopting Soil & People as the principal focus would help steer a holistic, evidence-based transition. The scale and compactness of Luxembourg's functional region makes this ambitious shared vision tangible.

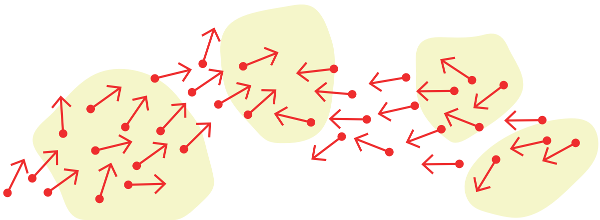
We take inspiration from already adopted actions, as our pilot tools. These initiatives with quantifiable outcomes can then be accelerated by coalition building and alignment with supporting initiatives that educate and raise awareness to increase their reach and gradually evolve towards a contributive territory.

As our next step we would like to further our understanding of existing initiatives , in and beyond the region, and create coalitions among them. We would like to identify the network of local actors who share our values and believe in our vision. We also aim to continue expanding and recalibrating our vision by collaborating with other teams who have been focusing on other sectors.

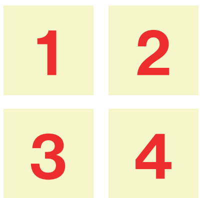
Our proposal anticipated a drastic shift in the dominant luxembourgish socio-economic model. A shift that requires us to rethink our relationship with the land in our vicinity and our behaviour as a society. How do we define growth? How can we live a more balanced life? Consume not too much, yet not too little? Can our jobs and homes be closer to each other? Do we need to change our diets? and can the Luxembourg territory produce the food that it consumes? This shift will be felt strongly, but with progressive steps it will bear fruit in time, for the economy, and society as well as the environment.

A shift that requires us to rethink our relationship with the land in our vicinity and our behaviour as a society.

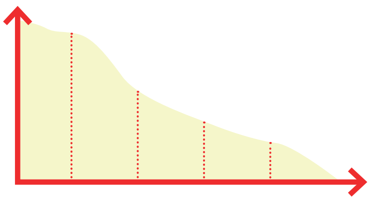
1.2 Methodology



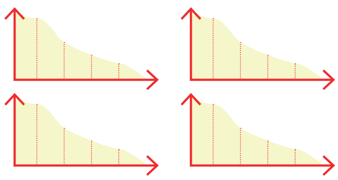
Learning from local initiatives



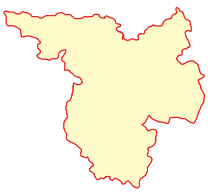
Identifying luxembourg's greatest challenges in relation to theme



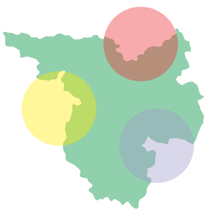
Projecting EU 1.5 LIFE scenario ambitions for Luxembourg's greater region



LULUCF tools and metrics



A bioregional vision



Potential implications for other sectors

1.3 Outlook

We are facing a new transition, and it is radically different from anything we have experienced in history. Seventeen of the eighteen warmest years on record have occurred in the 21st century. [2] The current climate crisis requires a deep shift in our societies and our economies. There is an urgent need for new ways to measure prosperity and wellbeing. In order to reach the 1.5°C heating target, we'll have to rethink the way we work, produce, live, move and eat. This existential challenge of the climate crisis overlaps however, with other transitions; AI, automatization and robotization, will drastically change the labor market and have profound socio-economic impacts on our society. So here lies a unique chance to address both topics: constructively tackle the societal shifts by solving the pressing environmental issue.

The abstraction of the goal, fueled by quantifications, technicalities, and biased opinions, ultimately acts as an obstacle to progress. Standalone local initiatives on the other hand, have been limited in expanding their reach due to a lack of a clear overarching direction.

There is a lot to tackle within Luxembourg's carbonising sectors, as there are many clear gaps. The current economic wealth is a crucial asset in promoting a transition. It's almost a responsibility. Additionally there is the region's natural abundance, which is for large parts an untapped resource. The extranational nature of Luxembourg is another aspect which can add further depth to the proposals as we must look beyond the national borders to get a wholesome picture. Lastly, the size of Luxembourg allows for structural changes, by policies or behavioral shifts, can on this scale have considerable, immediate and measurable effects. Its scale allows for a more harmonious alignment of local and regional policies. These 3 aspects together provide us with overlapping opportunities to reimagine the territory.

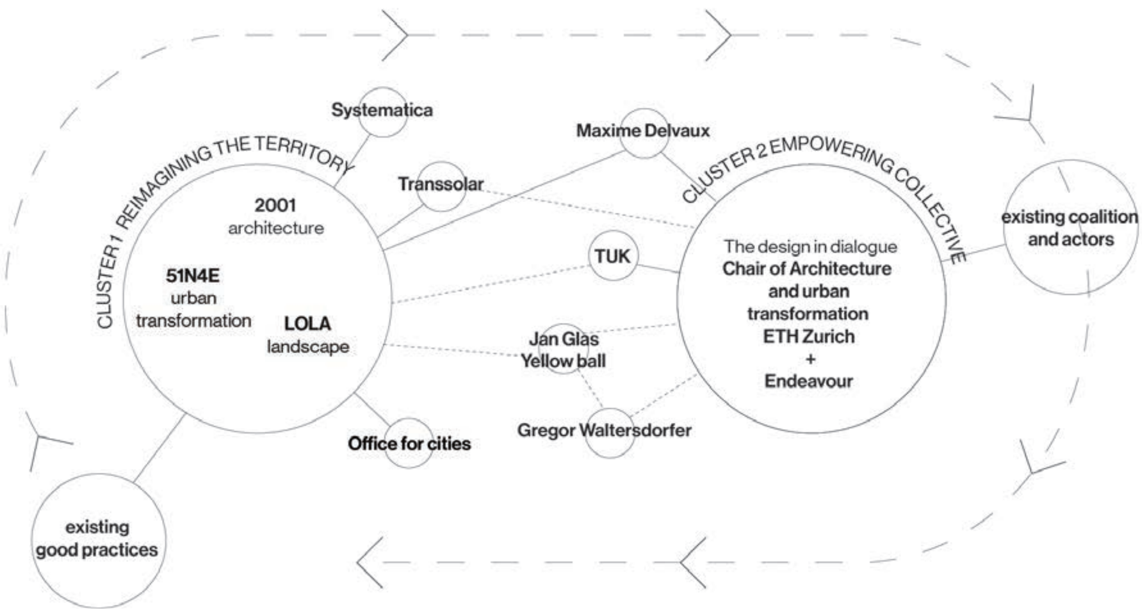
Our focus lies on two of the essential components of the transition: Soil and People. We take soil as our starting point. Soil is inherently a resource that our food, industries, and cities depend on. It also acts as a space for negotiation between interests and opportunities, policies and initiatives embedded in a geographical territory. Soil forms the common ground among the various actors of society and environment.

Terriotorial Consistency;
sourcing food locally by
regenerative agriculture.
enhancing carbon sinks.
Collective Sufficiency;
a balanced diet.
moving less, moving different.

We will concentrate on the underlying capacities of land, natural resources, and consumption patterns to push forward decarbonisation. We take inspiration from already adopted actions, as our pilot tools. These initiatives with quantifiable outcomes are then accelerated by coalition building and alignment with supporting initiatives that educate and raise awareness.

To us, indicators are not just goals, but rather values by which we structure our communities and economies. First and foremost, we intend to achieve a common ground among stakeholders that there needs to be a redefinition of how we evaluate growth. Environmental conditions and the wellbeing of ourselves and our ecosystems should have a central position in our new models for evaluation.
By proposing processes towards common goals that connect and build coalitions among initiatives and actors, we intend to overcome the democratic deficit, reveal opportunities for action and empower collectives in their existing strategies. We aim to articulate a vision where territorial consistency can coexist with collective sufficiency.

Our team is structured in two concurrent streams of expertise. The first stream revolves around wellbeing, participation, and Design in dialogue. While the second stream focuses on the territory through the lens of energy, transport, urban design, landscape design, cross-border Spatial planning, and economy. By recurrent exchange cycles, we strive for a collaborative effort which binds together these various specialisations into an interactive constellation.



A schematic composition of our team.

1.3 Outlook

In the plenary sitting of the European parliament of January 27th 2017, Luxembourg's Mady Delvaux presented a report with recommendations to the commission, on civil law rules on robotics.
"now that humankind stands on the threshold of an era when ever more sophisticated robots, bots, androids and other manifestations of artificial intelligence seem to be poised to unleash a new industrial revolution, which is likely to leave no stratum of society untouched, it is vitally important for the legislature to consider its legal and ethical implications and effects, without stifling innovation." [3]

The report is an attempt in anticipating technological developments that will induce major socio-economic shifts. The outlook of an ageing society along with jobs lost to robotization or AI, provoked Delvaux to raise the question of universal basic income (UBI) as a possible future necessity for social stability.

Beyond the societal and ethical questions problematized in the report, it outlines potential drastic change for the Luxembourgish model and hence its functional region.
As a study by the Brookings institute found that white-collar jobs are most exposed to AI, [4] the local service and specifically finance sector might witness (more) drastic losses, impacting not only the national economy, but foremost the demographic and social tissue of the entire Greater Region.

"Throughout history, large-scale sector employment declines have been countered by growth of new sectors that have absorbed workers" [5]

Thus, not 1 but 2 transitions have to be considered: first, the environmental challenge, which is strictly speaking existential for our living habitat, but will ultimately overlap with socio-economic shifts and first demands or needs.

Hence the current mission must be understood as an opportunity to proactively and quite opportunistically act on both urgencies: transsectoral synergies can be found and alliances between domains tied, mutually reinforcing the social acceptance as much as the political will to act.

In Gilbert Trausch's Histoire du Luxembourg: le destin européen d'un « petit pays », a discrete table illustrates the striking evolution of Luxembourg's active population, from 1870 to 2001. [6] Will the environmental transition produce a sustainable territory of knowledge, rebalancing the curve?

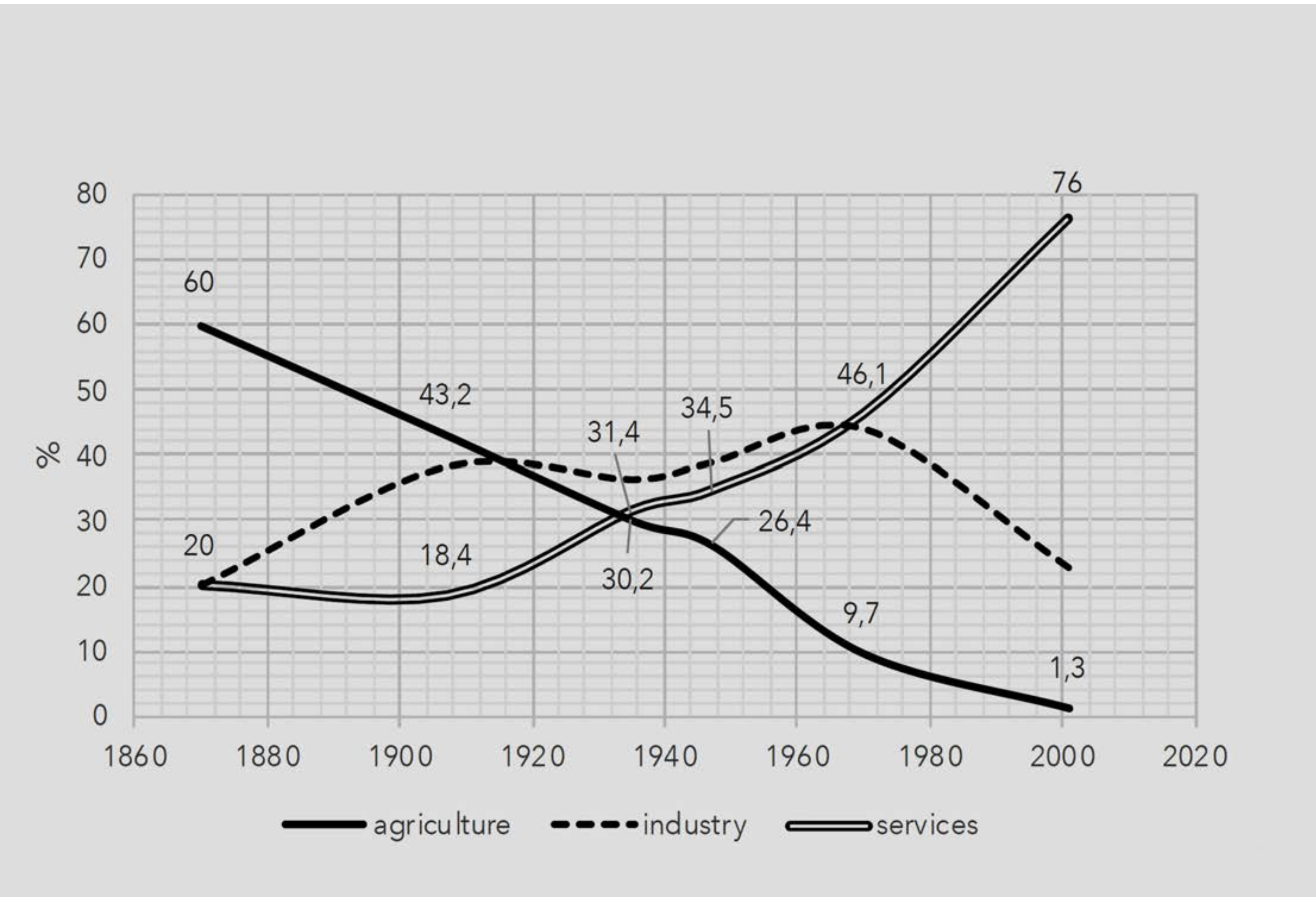


fig. a The striking evolution of Luxembourg's active population, from 1870 to 2001.

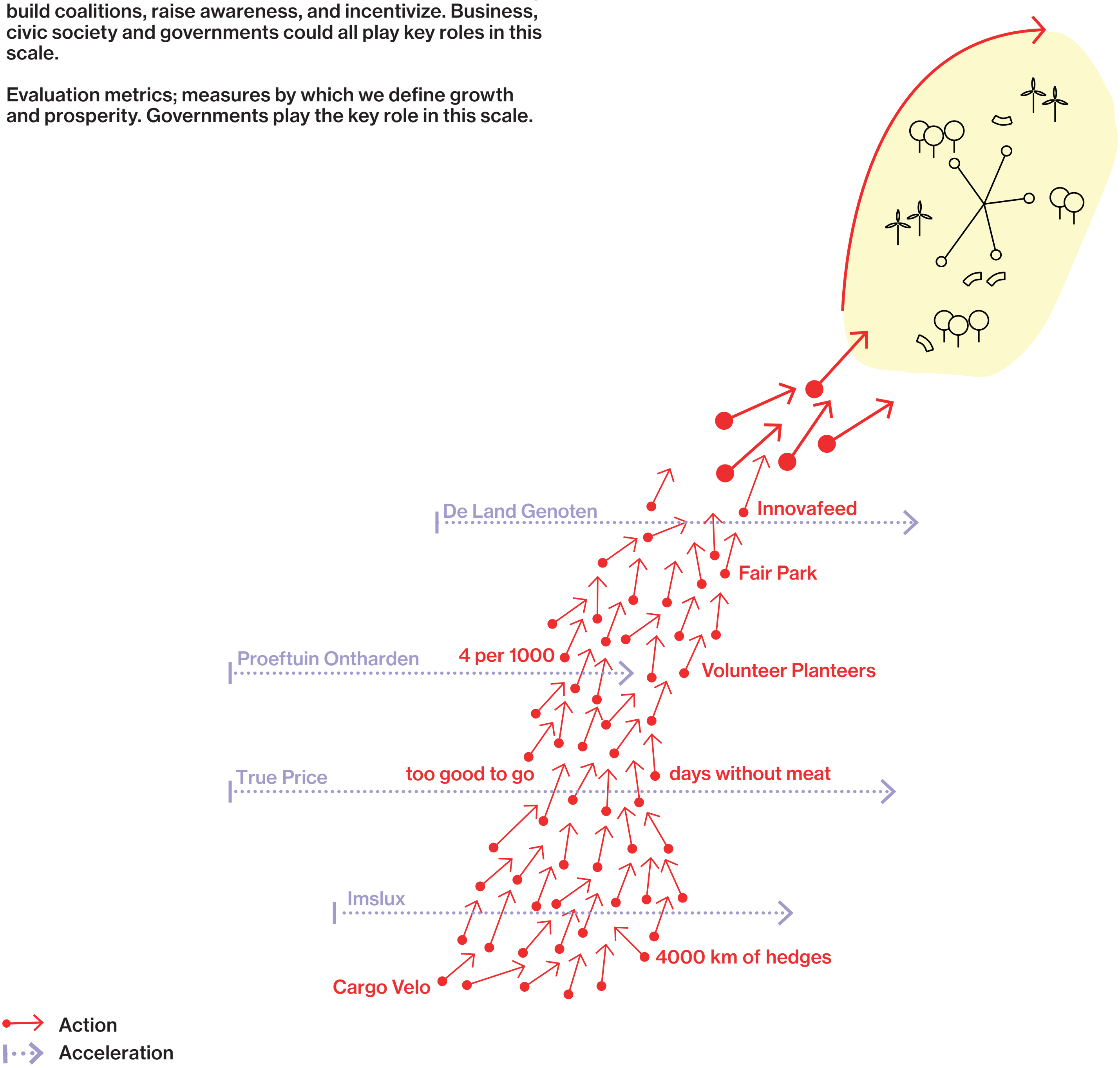
1.4 Action, Acceleration & Evaluation

After an in-depth study of existing local initiatives and their potential territorial impact we have selected 12 initiatives (presented in detail in the appendix) that represent exemplary efforts towards decarbonisation by lifestyle changes and nature-based solutions. We also identified 3 scales of metrics to be able to measure their territorial impact.

Action metrics; units to measure the quantifiable impact of individual initiatives. They form the building blocks of a territorial transition. Civic society plays the key role in this scale.

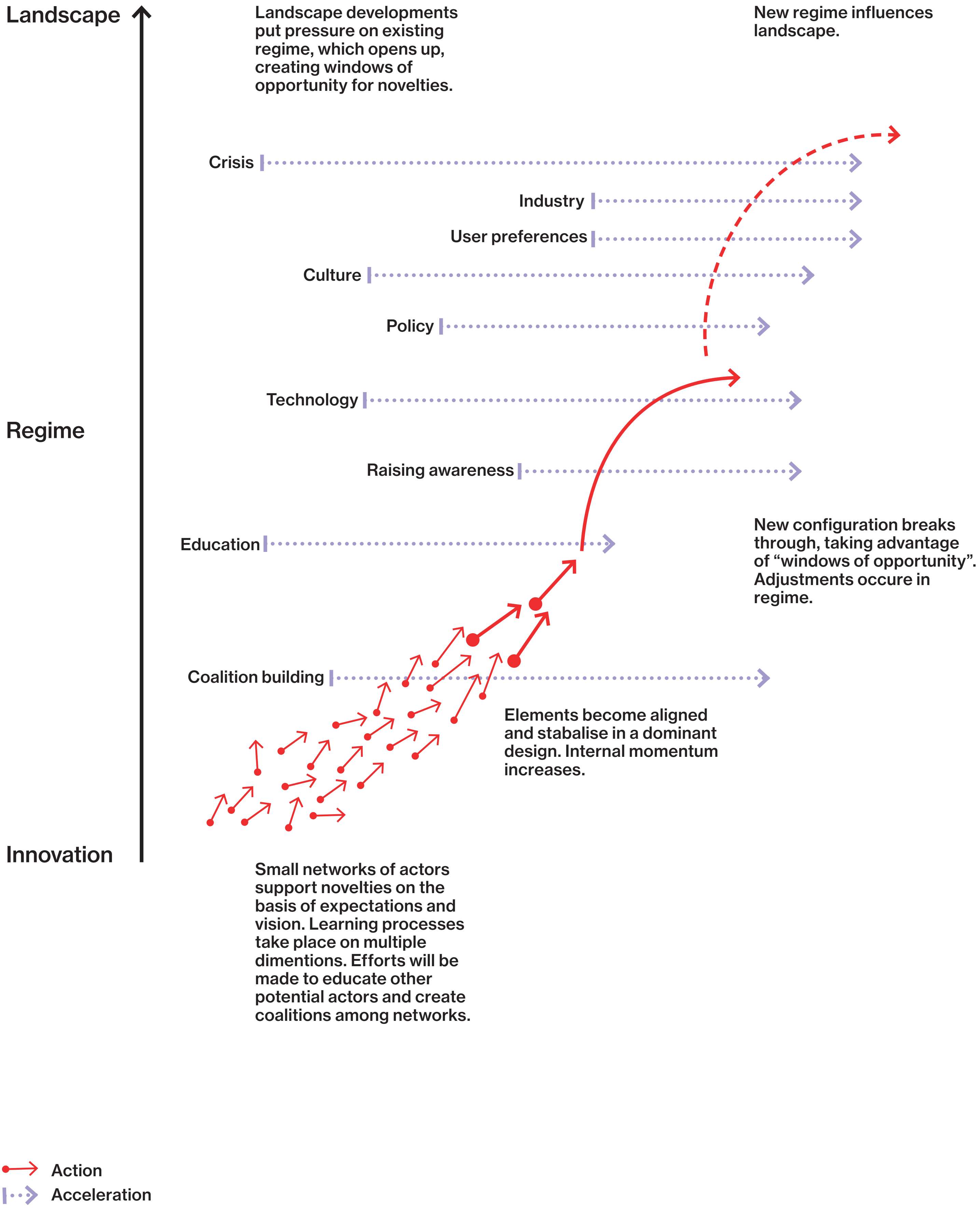
Acceleration metrics; frameworks to align initiatives and increase the reach and influence of actions. To this end they build coalitions, raise awareness, and incentivize. Business, civic society and governments could all play key roles in this scale.

Evaluation metrics; measures by which we define growth and prosperity. Governments play the key role in this scale.



The above mentioned initiatives are described in detail in the first segment of the appendix to this dossier.

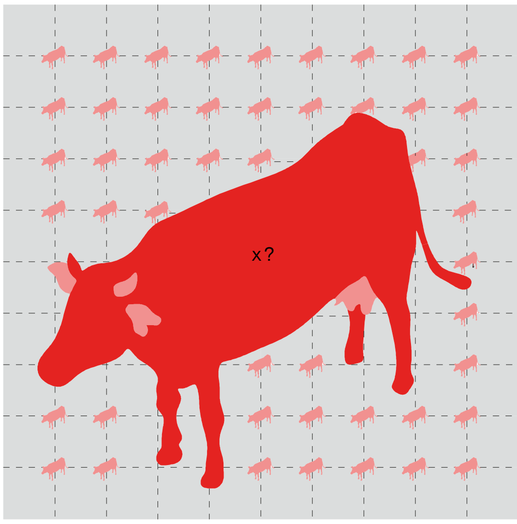
1.5 Territorial impact of initatives



Multi-level perspective on transitions (adapted from Geels 2002, 1263).

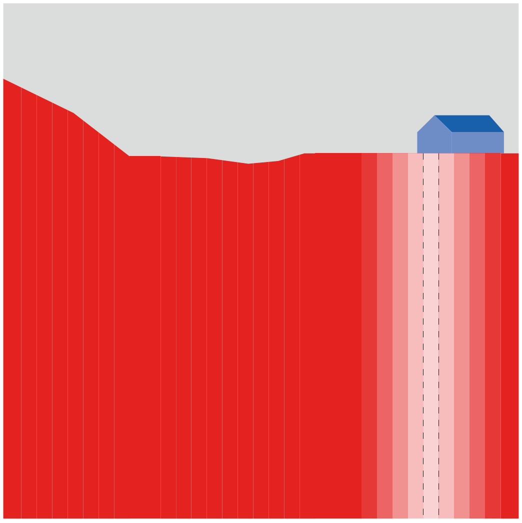
1.6 Key challenges

Soil



1. Agriculture

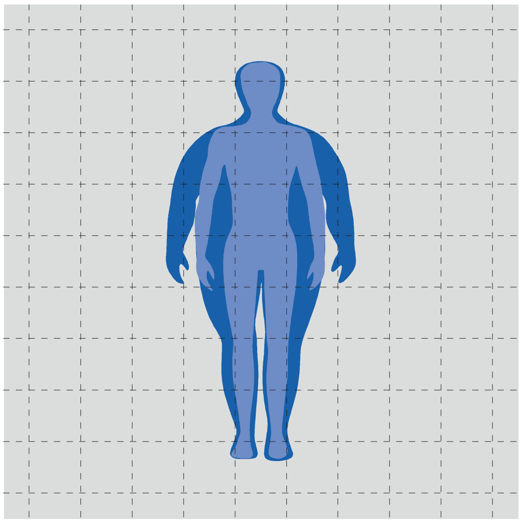
Meat production exceeds 15,000 tons annually so that the nation produces 40% more beef than it consumes. [7]



2. Carbon sink

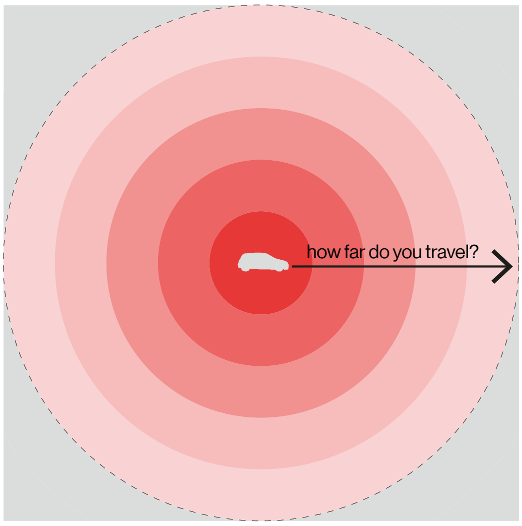
In 2010, in Luxembourg, only 2,7% of farms were practicing organic farming. [8]

People



3. Diet

Luxembourg is one of the countries recording the highest overweight rates in the world where 60.6% of the adults are overweight. [9]



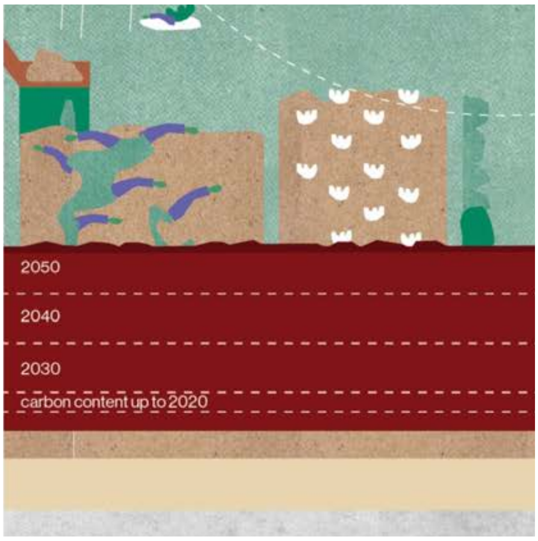
4. Proximity

It has the highest GHG emissions per capita in the EU at 20.5 MtCO2/capita, and 53% of it is from transport compared to the EU average which is 27%. [10]

1.7 Key questions

1. Agriculture

can agriculture be a positive force for carbon sequestration and climate adaptation?



2. Carbon sink

can we enhance our lands as carbon sinks?

3. Diet

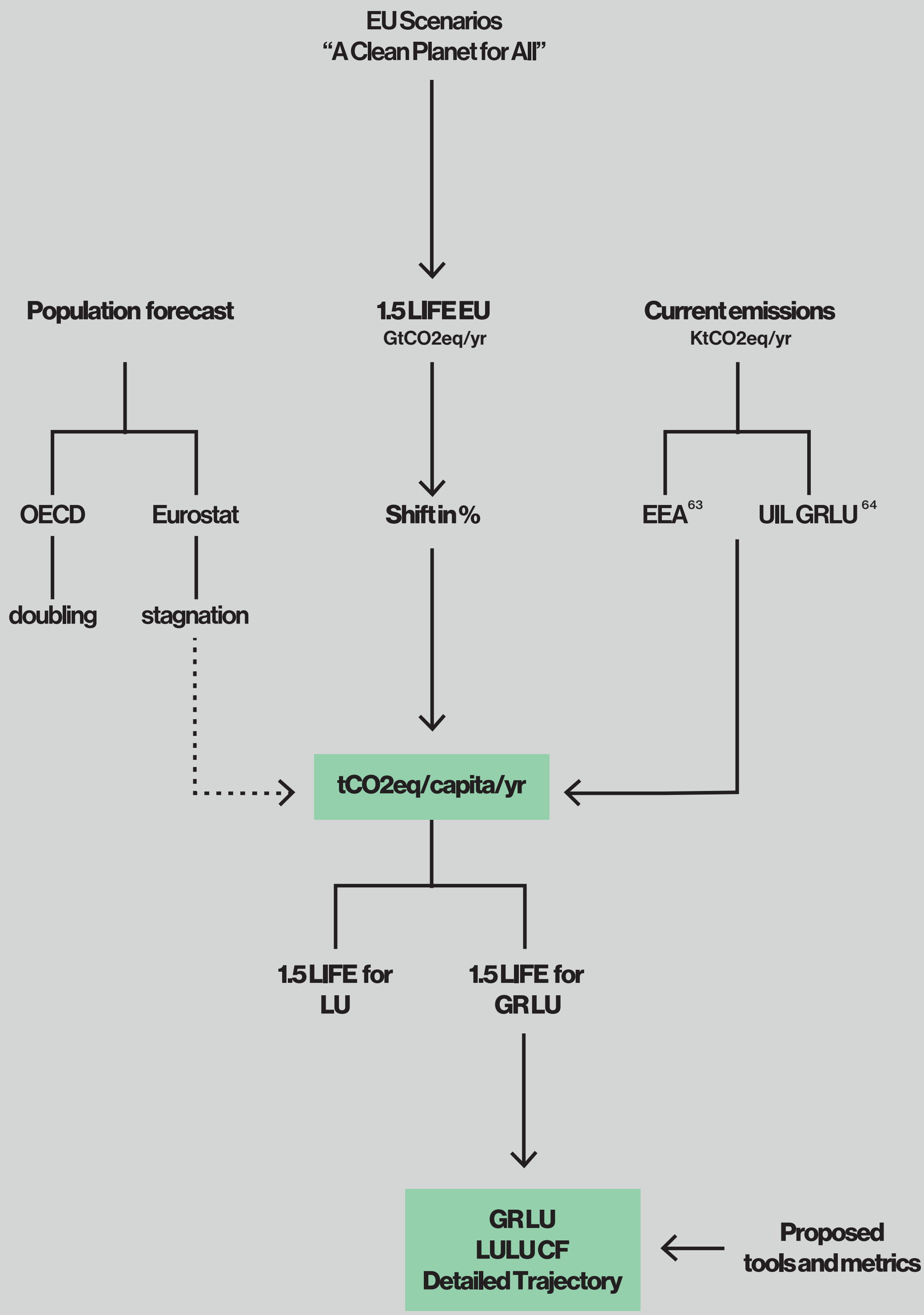
can we eat less and eat healthier?

4. Proximity

can our jobs, homes and resources be close to eachother?

TRANSITION

2.1 Flowchart of transition



2.2 EU long-term strategies

The scenarios put forward by the EC in the study of "A Clean Planet for All" investigate various pathways towards carbon neutrality.[11] As shown in the overview table, the only scenarios which achieve carbon neutrality by 2050, are the ones exploring the role of negative emissions in detail.

They achieve this by enhancing natural carbon sinks (mostly pursued by 1.5 LIFE) or by using carbon removal technologies (1.5 TECH) or combination of both. The 1.5 TECH scenario uses biomass for energy coupled with carbon capture and underground storage technologies (BECCS) and other similar technologies, although some of these are still in the testing phase. The 1.5 LIFE scenario focuses on consumption patterns, a circular economy, and a maximum enhancement of carbon sinks.

In 1.5 TECH, there is a great attention to the Carbon Capture and Storage (CCS), considering that BECCS and DACCS are the most important technologies taken into account in this scenario. Although known and deployed at commercial scale, they encounter two barriers. First the cost, (being particularly costly for processes emitting flue gas with a low concentration of CO2). The second barrier is the social acceptance for onshore storage in Europe, with the integrity of CCS, and the perceived risk of CO2 leakage, being a concern.

In 1.5LIFE, the combination of reduced energy consumption and increased availability of land allows for a potential larger role for afforestation and land restoration, reducing significantly the need for the deployment of biomass with CCS to achieve net zero GHG emissions.

1.5 LIFE reuses directly the CO2 captured while only 1.5 TECH conceives the long term geological storage.

In all scenarios, most of the CO2 stored underground is from fossil fuel origin and mainly captured in the industry sector. Only the 1.5 TECH differs with biogenic carbon supply in the largest share of technological carbon removal to generate negative emissions (BECCS) to offset the residual emissions and reach GHG neutrality by 2050. This is contrary to the 1.5 LIFE scenario that reduces further non-CO2 emissions and relies on a higher sequestration. Regarding non-CO2 emissions, these are lowest in the 1.5LIFE scenario because of assumed changes in dietary preferences.

The quantity of land that may be used for biomass production needed in the 1.5 TECH scenario could compete with other possible use of land. For example, the production of food. In this sense, the 1.5 LIFE scenario enables natural carbon sink while providing food. (See methods)

Also, the land used for biomass production (energy crops for instance) may have an impact on the ecosystems and the preservation of biodiversity. Also, the role of BECCS in the long term will depend on the ability to supply large amounts of biomass in a sustainable way, and on the development of CCS technologies.

**The LIFE scenario priorotises lifestyle changes and enhancement of natural sinks, while TECH focuses on carbon removal technologies.
The LIFE scenario achieves similar decarbonisation targets to TECH with considerably lower monetary investment.
In addition, the LIFE scenario contributes to restoration and enhancement of biodiversity, while the TECH scenario may have a negative impact on them.**

2.3 1.5 LIFE scenario as our benchmark

	Electrification (ELEC)	Hydrogen (H2)	Power-to-X (P2X)	Energy Efficiency (EE)	Circular Economy (CIRC)	Combination (COMBO)	1.5°C Technical (1.5TECH)	1.5°C Sustainable Lifestyles (1.5LIFE)
Main Drivers	Electrification in all sectors	Hydrogen in industry, transport and buildings	E-fuels in industry, transport and buildings	Pursuing deep energy efficiency in all sectors	Increased resource and material efficiency	Cost-efficient combination of options from 2°C scenarios	Based on COMBO with more BECCS, CCS	Based on COMBO and CIRC with lifestyle changes
GHG target in 2050	-80% GHG (excluding sinks) ["well below 2°C" ambition]					-90% GHG (incl. sinks)	-100% GHG (incl. sinks) ["1.5°C" ambition]	
Major Common Assumptions	• Higher energy efficiency post 2030 • Deployment of sustainable, advanced biofuels • Moderate circular economy measures • Digitilisation • Market coordination for infrastructure deployment • BECCS present only post-2050 in 2°C scenarios • Significant learning by doing for low carbon technologies • Significant improvements in the efficiency of the transport system.							
Power sector	Power is nearly decarbonised by 2050. Strong penetration of RES facilitated by system optimization (demand-side response, storage, interconnections, role of prosumers). Nuclear still plays a role in the power sector and CCS deployment faces limitations.							
Industry	Electrification of processes	Use of H2 in targeted applications	Use of e-gas in targeted applications	Reducing energy demand via Energy Efficiency	Higher recycling rates, material substitution, circular measures	Combination of most Cost-efficient options from "well below 2°C" scenarios with targeted application (excluding CIRC)	COMBO but stronger	CIRC+COMBO but stronger
Buildings	Increased deployment of heat pumps	Deployment of H2 for heating	Deployment of e-gas for heating	Increased renovation rates and depth	Sustainable buildings			CIRC+COMBO but stronger
Transport sector	Faster electrification for all transport modes	H2 deployment for HDVs and some for LDVs	E-fuels deployment for all modes	Increased modal shift	Mobility as a service			• CIRC+COMBO but stronger • Alternatives to air travel
Other Drivers		H2 in gas distribution grid	E-gas in gas distribution grid				Limited enhancement natural sink	• Dietary changes • Enhancement natural sink

fig. 1: Scenarios comparison from EC in the study of "A Clean Planet for All".

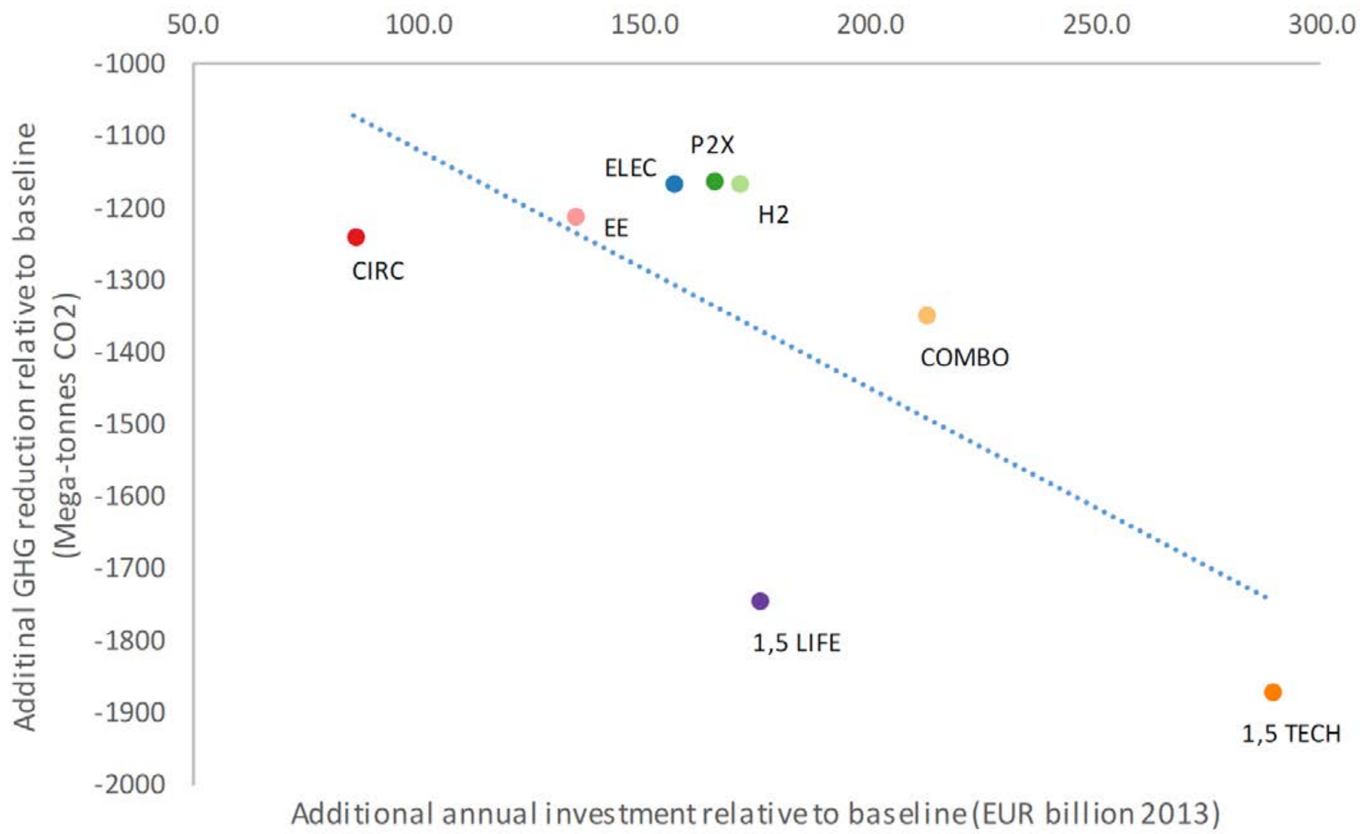


fig. 2: Additional annual investment relative to baseline from EC in the study of "A Clean Planet for All".

2.4 EU 1.5 LIFE scenario projections

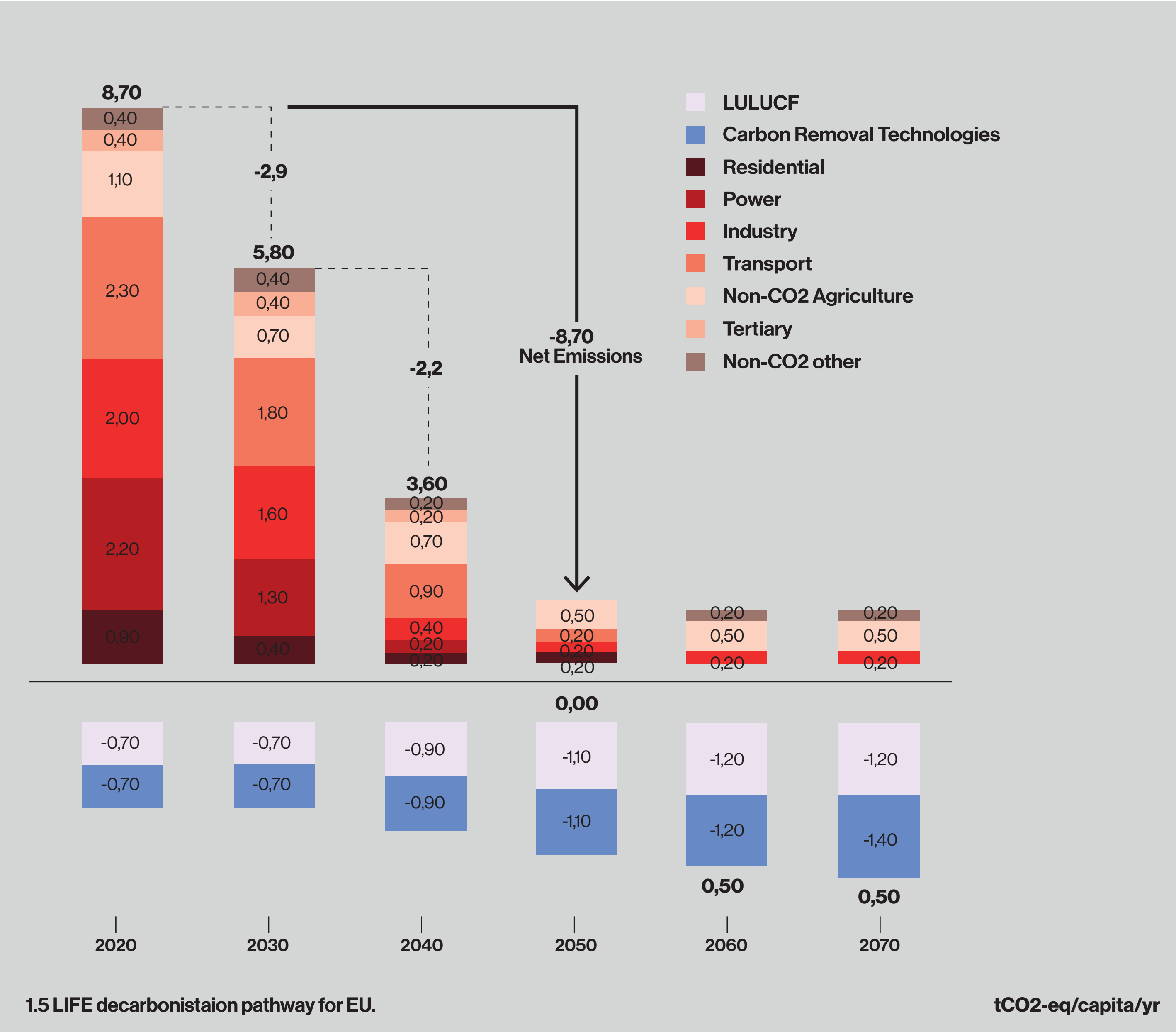
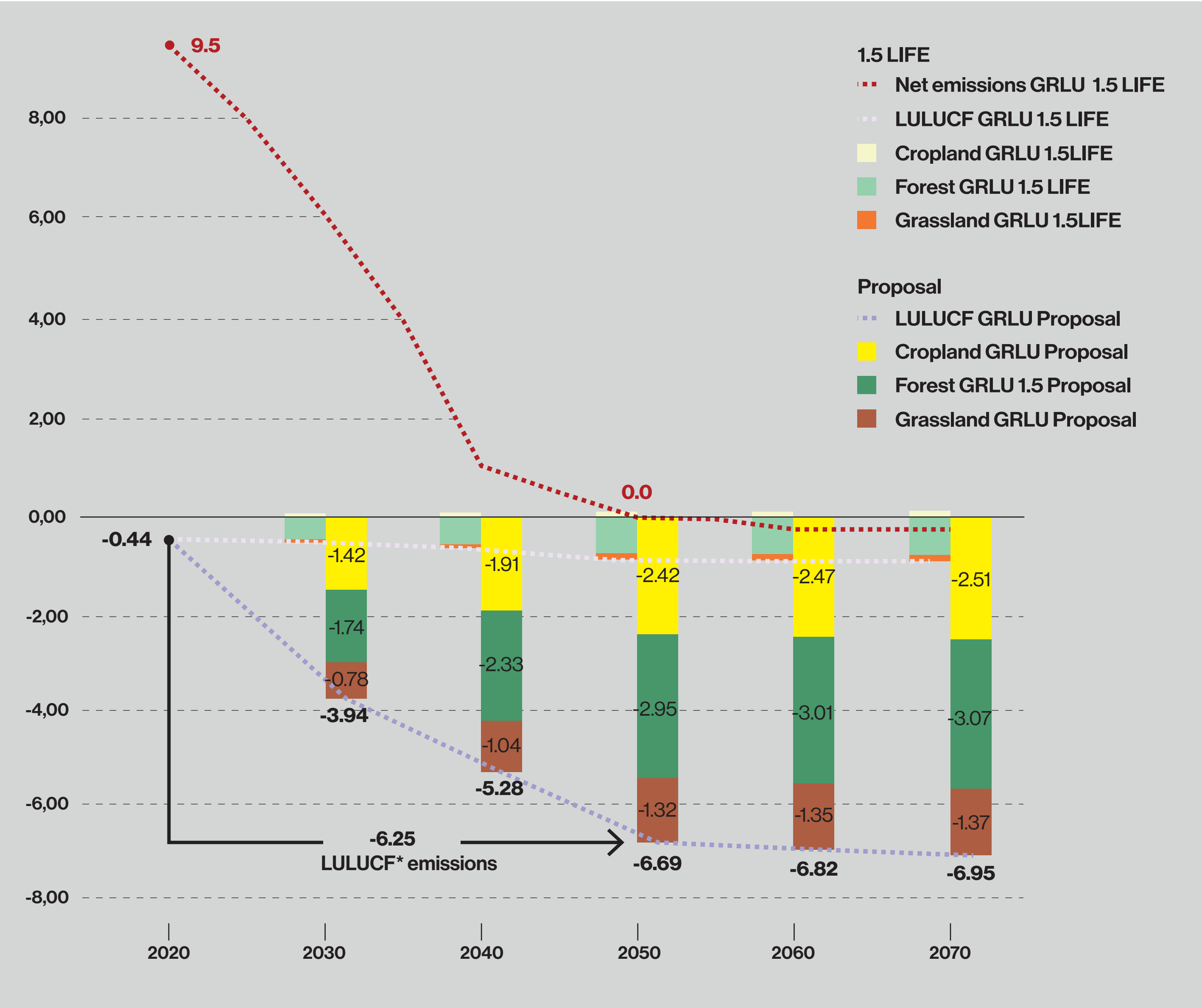


fig. b

We adopted the *t CO2/capita* unit to be able to translate the ambitions set by the EU for GRLU. The 1.5 Life scenario projected for GRLU provides an ambitious baseline aligned with our approach.

Through agriculture, carbon sinks and diet shifts, we provide the tools and metrics to exceed the LULUCF goals for this scenario. Implementation details for these tools need to be investigated and applied to the chart in the upcoming phases.

2.5 GRLU proposal for decarbonisation



Proposed decarbonisation pathway for LULUCF sector of GRLU, relative to 1.5 LIFE baseline.

fig. c

1. Agriculture TnCO2-eq/yr

1. Adapted to a balanced diet
2. Plant protein needs considerable less surface area to produced the same amount of kcal(1,3% of the area needed for beef).
3. Increasing in yield
4. Converting the reclaimed land to forests.

2. Carbon Sinks TnCO2/ha

1. Organic matter additions to croplands
2. Zero tillage on croplands
3. Crop covers
4. Hedges on croplands and pastures
5. Alternative forest managment
6. Silvo-pastures

3. Diet Kcal/capita/day

1. Overall reduction of consumed meat
2. Replacement by plant protein
3. Shift from bovine and pig meat, and more sheep and goat meat

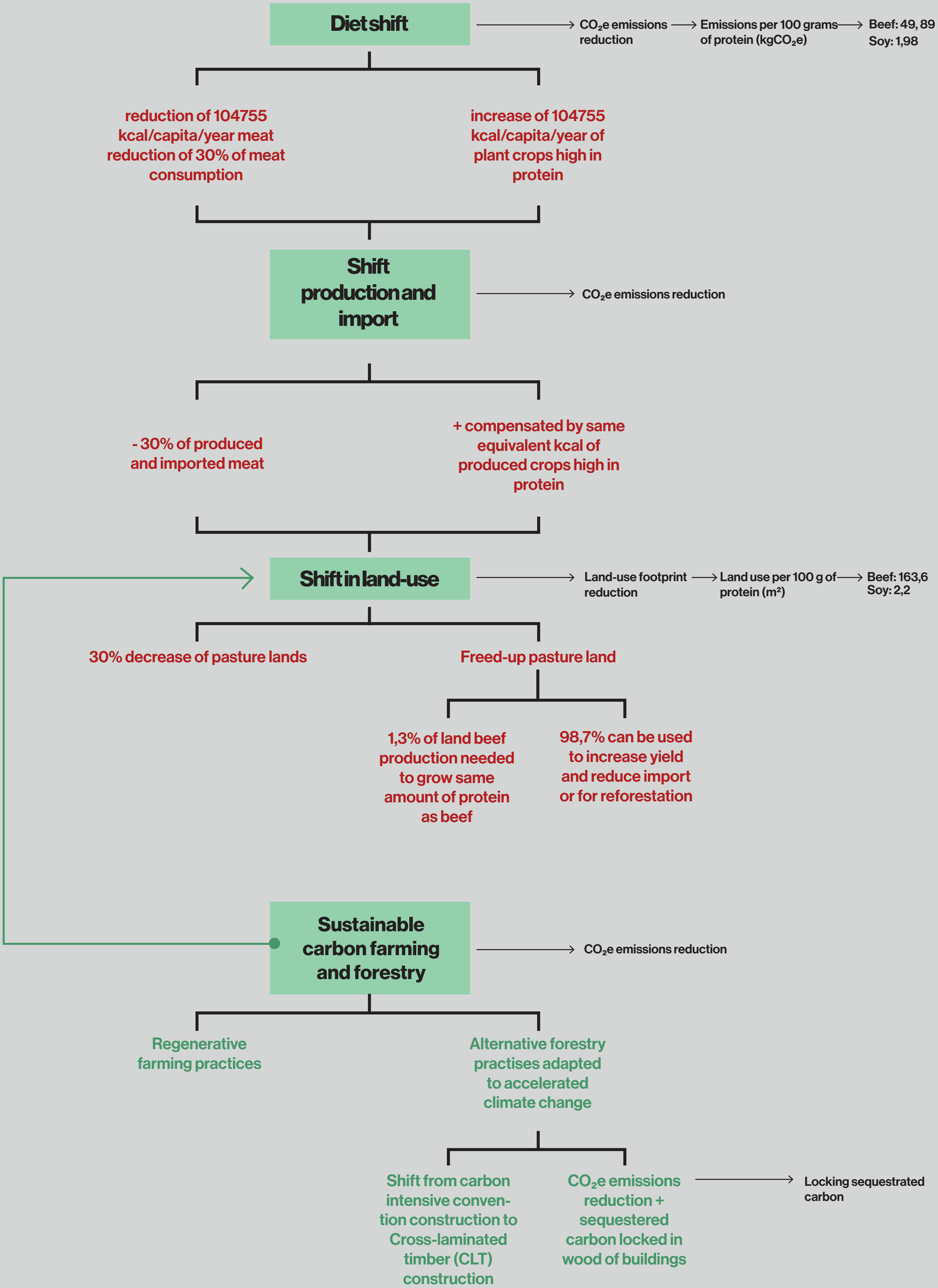
Please note, a more drastic change towards veganism (50% of population) can reduce GHG even more and free up more land from livestock production and increase the total agricultural yield and/or forest cover greatly.

*LULUCF in this chart only takes into account forests, croplands and grasslands.

LULUCF
TOOLS & METRICS

DIETARY SHIFTS
AGRICULTURE
CARBON SINKS

3.1 Flowchart of tools & metrics



3.2 State of affairs

While the accumulating effect of carbon sequestration, and vegetation can make soil an essential storage for carbon, the current land and soil management practices in the GRLU are depleting the carbon stock capacity at a fast rate. This in result has transformed the land from a carbon sink towards a source of releasing carbon into the atmosphere. We describe the specific situation in Luxembourg to illustrate the key drivers behind this degradation:

One of the main drivers in this degradation is the shift towards large scale highly mechanical industrial agriculture. The number of farms of 2 ha (5 acres) or more fell from 10,570 in 1950 to 2,314 in 2001, and the average holding increased from 13.16 to 55.17 ha. [12] The way crops are produced with mechanical tillage of soils and monocultures of extraction have severely depleted soils resulting in an average carbon content loss of 0.6%/year for cropland. [13]

On top of that, the high application rates of inorganic N fertilizers (3400 tones in 1950 and 13795 tones in 2019) affect the buffering capacity of the soil to hold organic carbon, resulting in low soil biodiversity and fertility. [14] Another main driver is the extensive livestock production which accounts for 80 percent of agricultural profits for the country. The growth of the cattle industry has led to an increase in dairy products and to the production of corn as livestock feed. Farming cattle for meat or milk is a very inefficient method of protein production with a high land, and carbon footprint. [15]

To illustrate this, 100 grams of beef protein has 49.89 kgCO2eq GHG while 100 gram of Tofu (soybeans) has only 1.98 kgCO2eq GHG [16], and 100 grams of beef protein requires 163.6 m2 of land while 100 grams of tofu (soybeans) only requires 2.2 m2 of land to be grown. [17]

The last main driver is the degradation of Luxembourg's forests. Due to development the country's forests are getting more and more fragmented. Poor management and air pollution have had severe effects on the health of the forests. While only 4,2% of trees were damaged in 1986, in 2019 that number increased to 50%. [18] Also the loss of sequestered carbon stock due to unsustainable harvesting of wood, that is not decomposed at the end of its lifespan or used as woodfuel, is considerable (-200 Gg C/yr). [19]

Considering this layered degradation, it becomes apparent that Luxembourg has been gradually moving away from using its territory as a carbon sink. Instead, it has become a source of emissions itself.

image 3: Soil degradation. (2019)

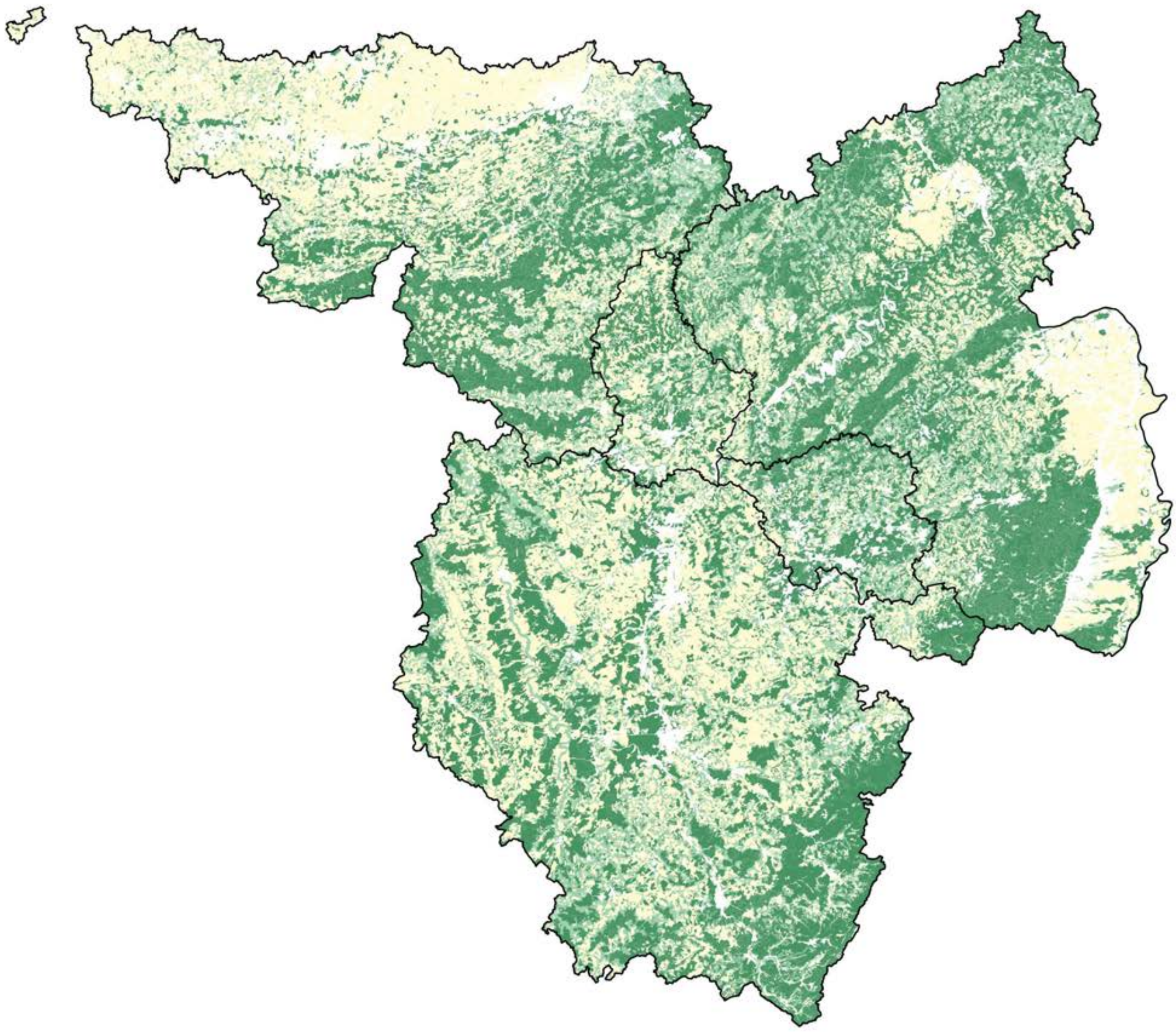
image 4: Pastures and livestock. (2014)

image 5: Forest degradation.(2019)

image 2: Cropland (2019)

image 6: Luxembourg first to ban Glyphosate. (2020)

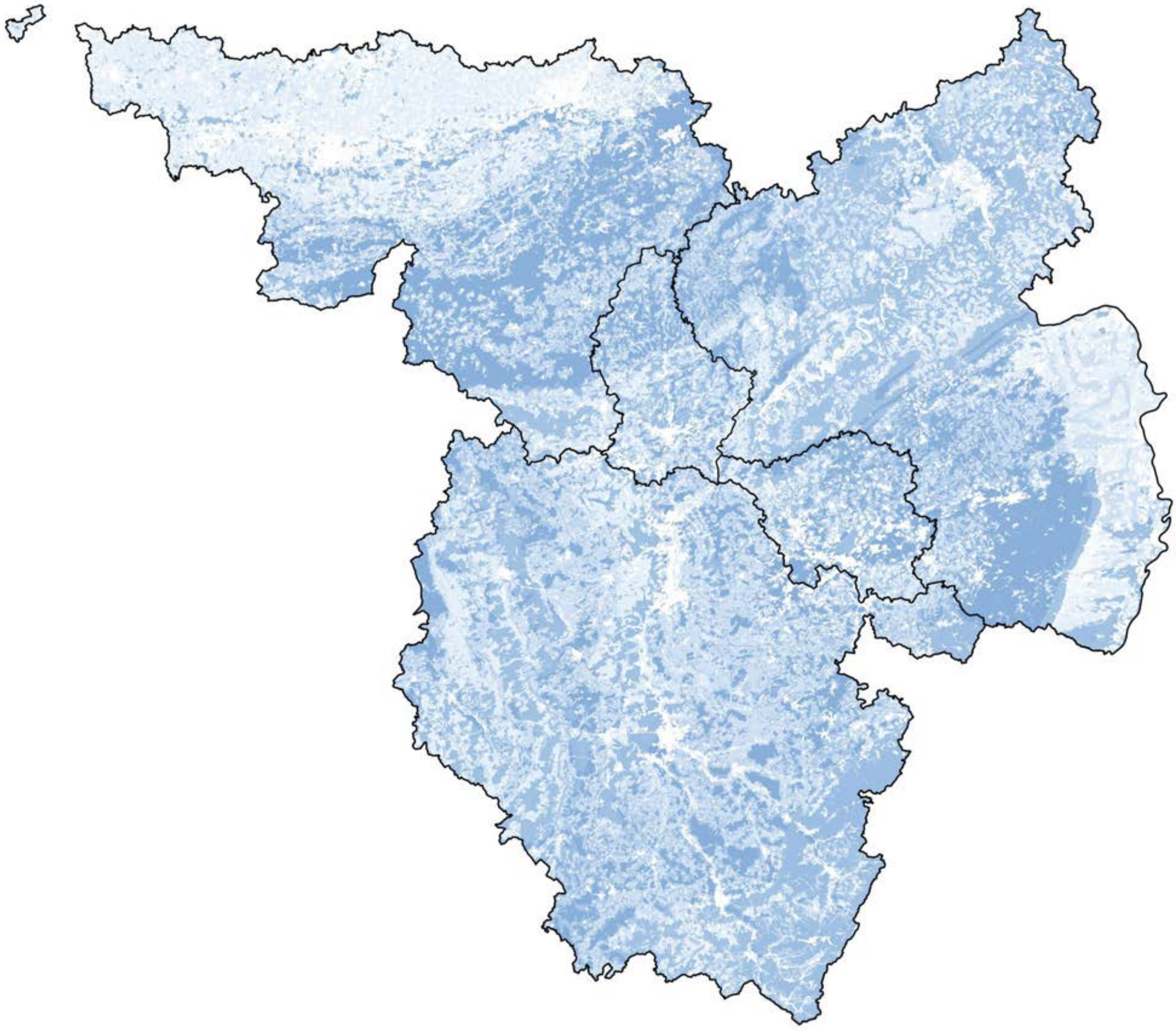
3.3 Current land use distribution



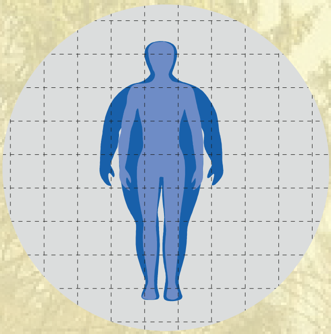
Forests Grassland Cropland

3.4 2020, current carbon sink

Current areas with high organic carbon content relate to forested areas and more loamy soils. The limited capacity of the current agricultural land as a carbon buffer is apparent.

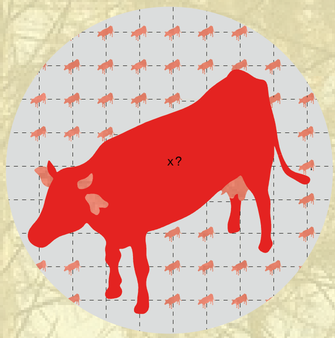


50-70 t C/ha 100-120 t C/ha 120-140 t C/ha 180-200 t C/ha 200-220 t C/ha 220-240 t C/ha diet



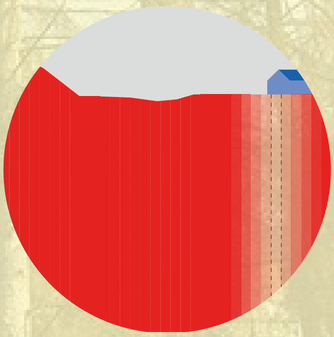
eating
less meat

land use



using
less land

sequestration



enhancing
carbon sinks

3.5 LULUCF & Dietary shift
Lower meat consumption

Land use, and especially agricultural land, is greatly influenced by our lifestyles. The supply of food adapts to user preferences and market demand. This is why to be able to address the territorial distribution of croplands and pastures, we first need to understand the potential shifts in diet.

The current average diet in Luxembourg currently includes 340345 kcal/capita/yr of meat. [20] Within the study of "A Clean Planet For All" there are a series of dietary shifts proposed by the European commission, including Diet 5 which proposes a bold reduction of consumed meat. (fig.4) The diet 5 trajectory applied to the current status of the Luxembourg diet, suggests a downward shift to 235790 kcal/capita/yr of meat and a replacement of 104555 kcal/capita/yr by plant protein.

Not only does diet 5 include a reduction of consumed kcal of meat but also a shift in types of meat consumed; less bovine(60 kg CO2eq/kg food) and pig meat and more sheep and goat meat (24 kg CO2 eq/kg food) that will lower the total carbon footprint as well.

Replacing part of meat consumption with plant protein, and less carbon eq intensive meat types (shift from beef to sheep and goat) reduces the CO2 eq emissions of dietary habits considerably.

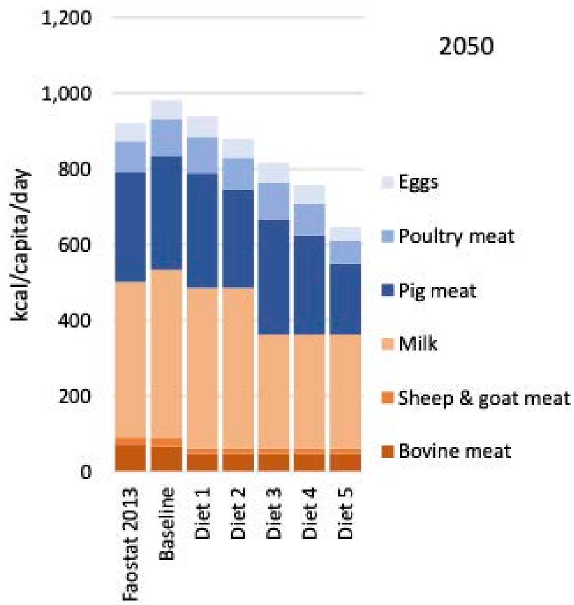


fig. 4: summary of diet proposals

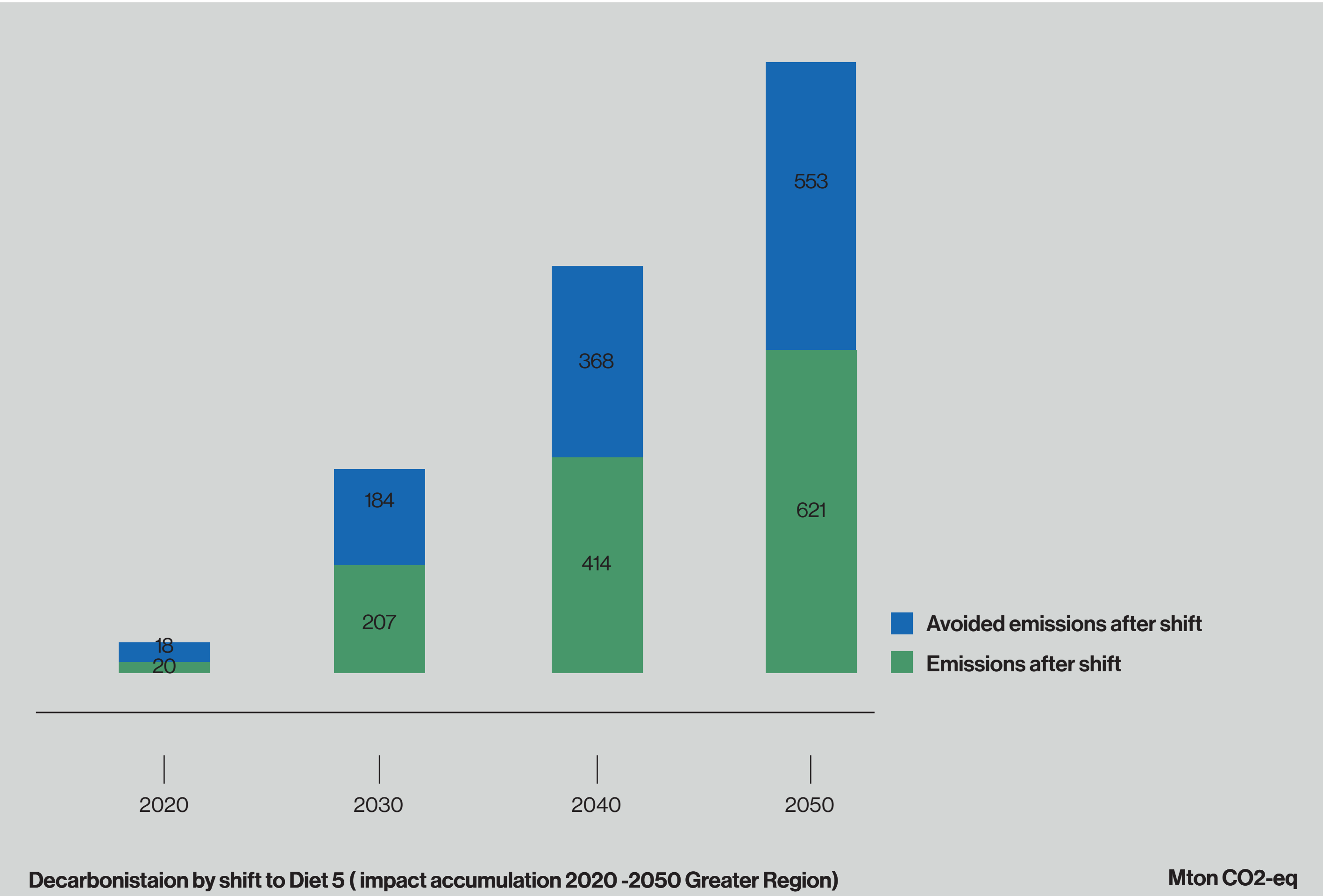


fig. d: Diet shift (impact accumulation 2020 -2050 GRLU)

3.5 LULUCF & Dietary shift
Food production & import

If we take the diet 5 trajectory as the benchmark for Luxembourg's user preferences, a greater shift will begin to occur on the production and supply chains of food.

Consumption of less meat and more plant based protein, will result in the replacement of meat production and import (international production), with crops (that are high in plant protein) production and import.

Our calculations of this shift presented below, are based on the food production and import data of Luxembourg.(figures 9-14) We have applied the ratio of Luxembourg's population in relation to its food production and import, to be able to extrapolate the potential results for the Greater Region.

The economic implications of this shift in production and import are yet to be investigated. What is clear is that as well as the challenges that the food and agricultural sectors will face, there will be many new opportunities.

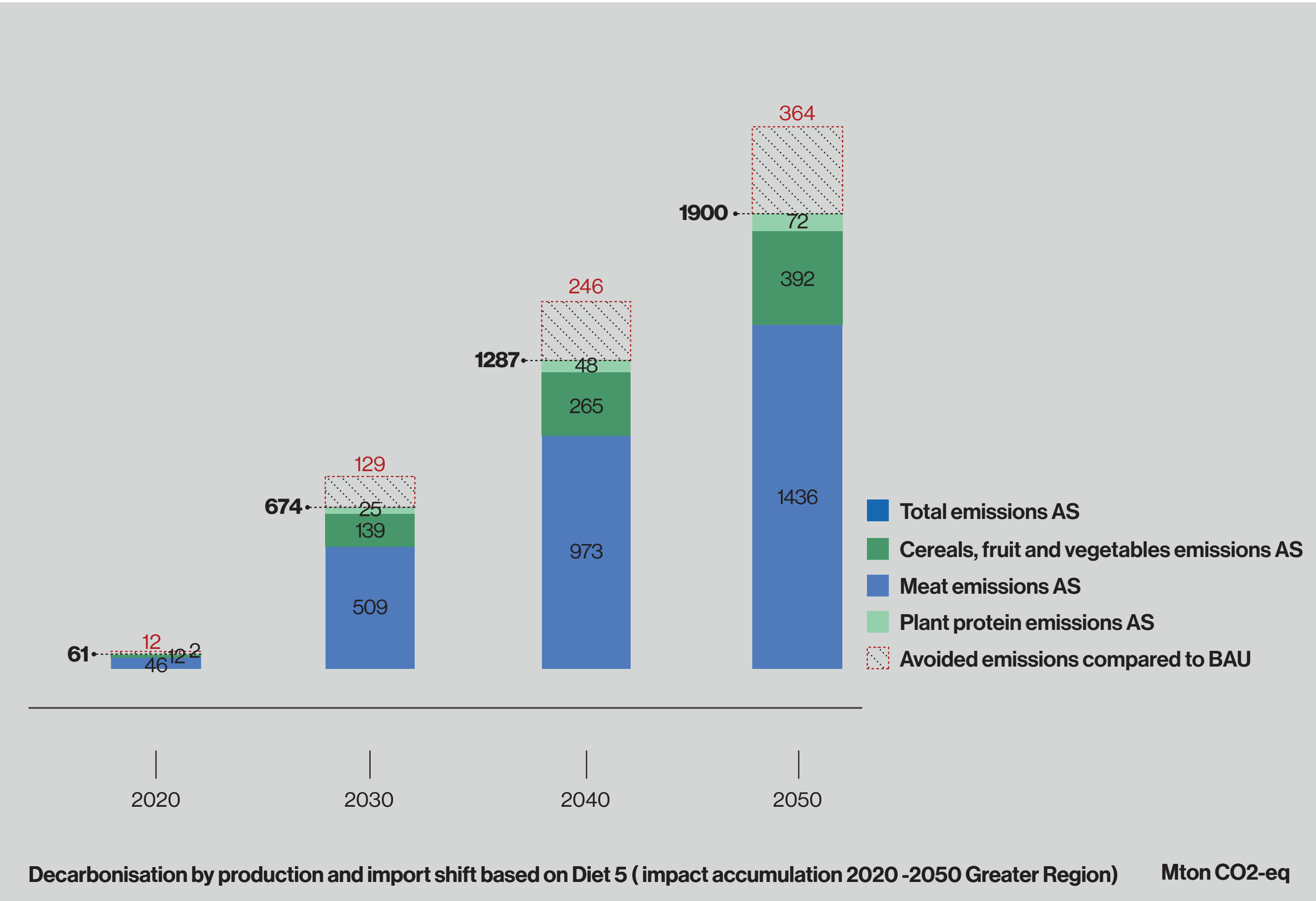


fig. e: Production and import shift (impact accumulation 2020 -2050 GRLU)

3.5 LULUCF & Dietary shift
Shift in land use

A decrease in meat consumption, and compensation by a relative increase in plant-based protein consumption, results in a shift in land-use.

Beef needs 163,3 m² of the land per 100 grams of protein and soy only 1,3% of that land to produce the same amount of protein (2.2 m²). [21]

This means that not only pasture land is freed up with this shift in production, but also the available land can be used more efficiently.

An alternative land use is to increase the overall crop yield of the arable land for the Greater Region, and in return reduce the international dependance and ecological footprint of imported food products.

Another alternative is to use the land for reforestation. In our calculation we decided to project a shift for 1.3% of the freed-up pastures to crop production and the other 98,7% to reforestation.

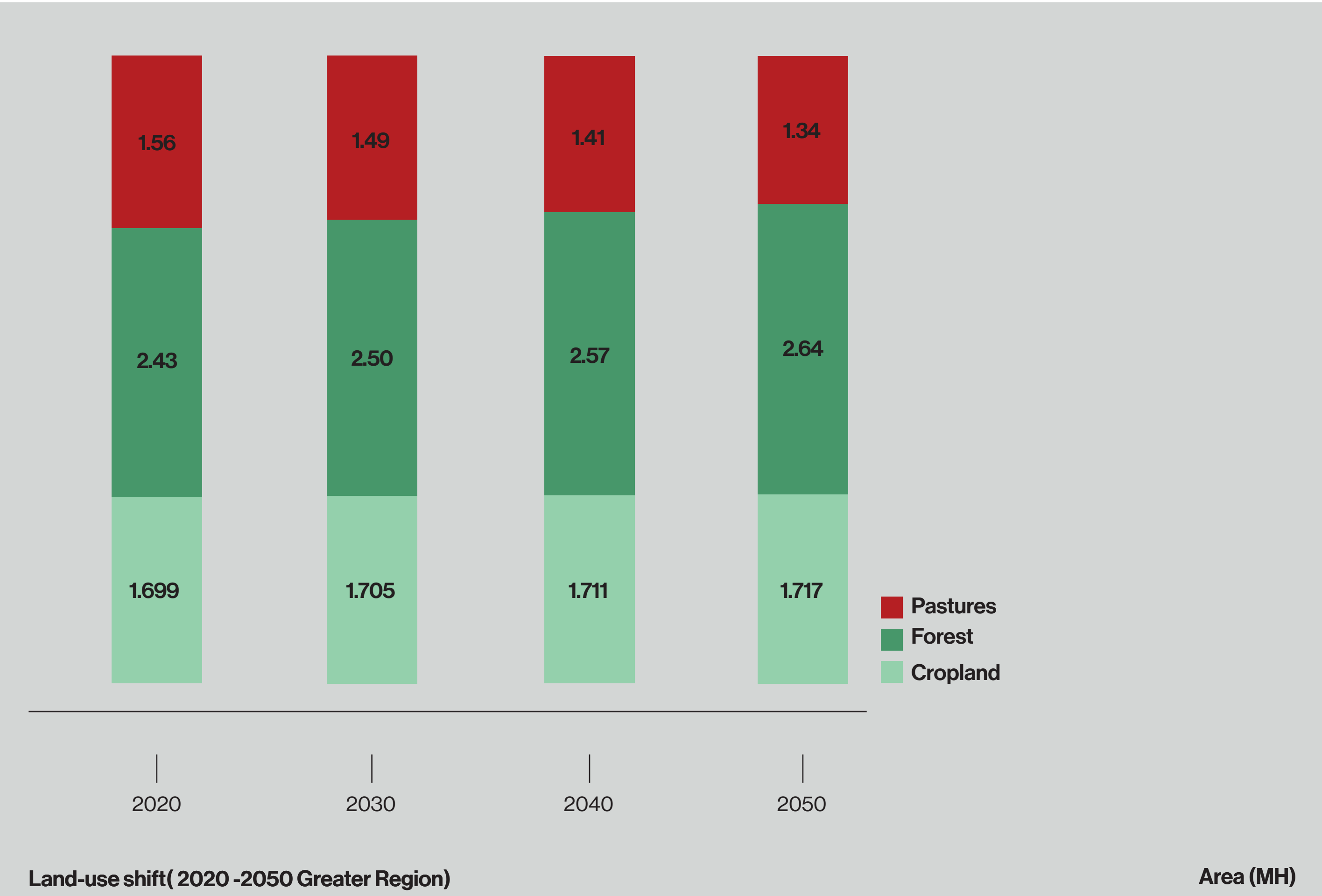


fig. f: Landuse shift (impact accumulation 2020 -2050 GRLU)

3.6 Sequestration tools

Tool 1: Organic matter additions to croplands
Actively building soil by using organic waste as a source and applying it to cropland increases soil organic carbon (SOC), soil health and soil fertility. The organic waste sources with the highest potential are biosolids and green compost waste due to SOC increase, inorganic fertilizer reductions and N2O emission reductions.

Tool 2: Zero tillage on croplands
Avoiding tillage increases the retention of soil organic matter and restores the biodiversity of the soil.

Tool 3: Crop covers
Cover crops manage soil erosion, soil fertility, soil quality. They are planted as off-season crops after harvesting the cash crop. Also called "green manure", they are typically high in nitrogen so that the needs for inorganic fertilizers in crop production is drastically reduced. Cover crops also improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time.

Tool 4: Hedges on croplands and pastures
The western part of Europe`s ancient rural landscape was characterized by a network of hedgerows. Luxembourg has lost these landscape features. The neighboring region of Wallonia has declared to reconstruct 4000 km of hedges. Two effects of hedges on SOC storage are evident: local effect of SOC storage under the hedge itself and an anti-erosive effect locking SOC at the hillslope scale.

Tool 5: Alternative forest management
Shift towards alternative forest management activities that increase stand-level forest carbon stock and account for climate change-induced productivity and species suitability. Luxembourg`s forest would become more healthy and resilient to climate change and diseases. These approaches come down to a reduction of the length of harvesting and adapt species composition to those species that are expected to perform better under a changing climate.

Tool 6: Silvo-pastures:
By integrating trees, forage, the pastures grazed by cattle will increase in overall productivity and long-term income due to the simultaneous production of tree crops, forage, and livestock, and significantly increase carbon sequestration.


image 8: Compost application.(2017)


image 9: Cover crop. (2020).


image 10: Environment management. (2020).


image 7: Silvo-pastures (2018)


image 11: Climate-proof forests (2020).

3.6 Sequestration tools

The chart below presents the application of the sequestration tools discussed, over the proposed land use changes in this chapter on the scale of the territory.

The individual sequestration impact of the proposed regenerative agricultural practises are based on the mean results from test field experiments done in Western Europe. In these studies the sequestration impact is compared with reference fields with no regenerative agricultural practices applied, or the SOC levels before intervention.

The key takeaway is that when we consider the territory as a regenerative system and as a holistic carbon sink, we can greatly maximise its capacity for carbon sequestration and storage. To achieve this vision, each of the proposed shifts and tools are an essential part of the roadmap. There are also other potential decarbonising tools that can benefit from the byproducts of the proposed shift in the LULUCF sector and could be further investigated. An example of this, is using the harvested wood from forests for construction of new houses. This will result in substantial emission reductions in the industry sector. Further information on this insight could be found in the last chapter.

The total carbon sink is the cumulative result of the sequestration impact of all proposed tools. However when several tools are simultaneously applied to croplands we assume that their impacts will overlap and the total sequestration capacity will be not as high as the theoretical sum.
Another important notion is that our results are based on the initial rate of SOC increase and annual accumulation. However, the soil carbon content will reach an equilibrium/ saturation level over time. From that point on, efforts should be directed to keeping the stored carbon stocks locked.

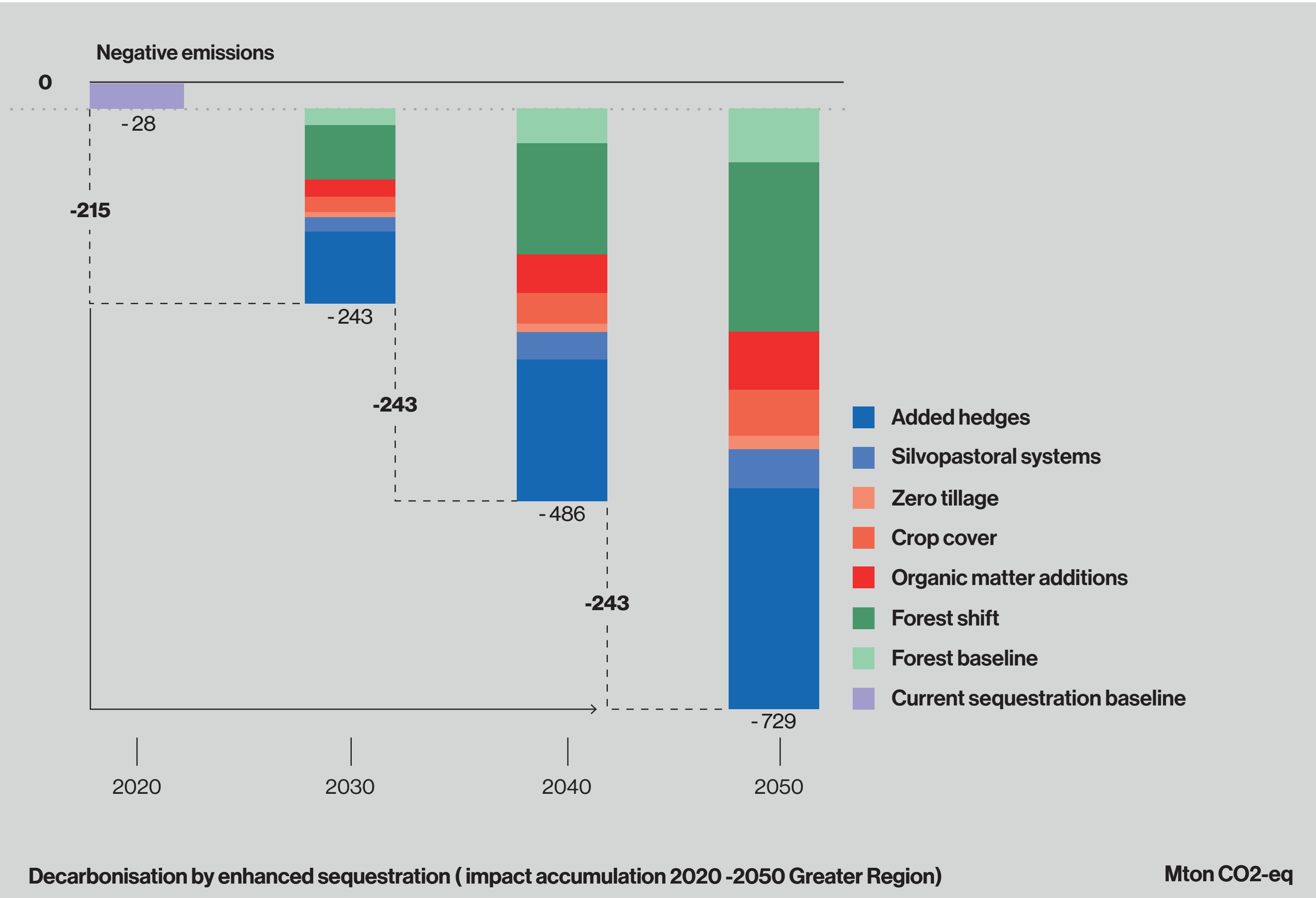
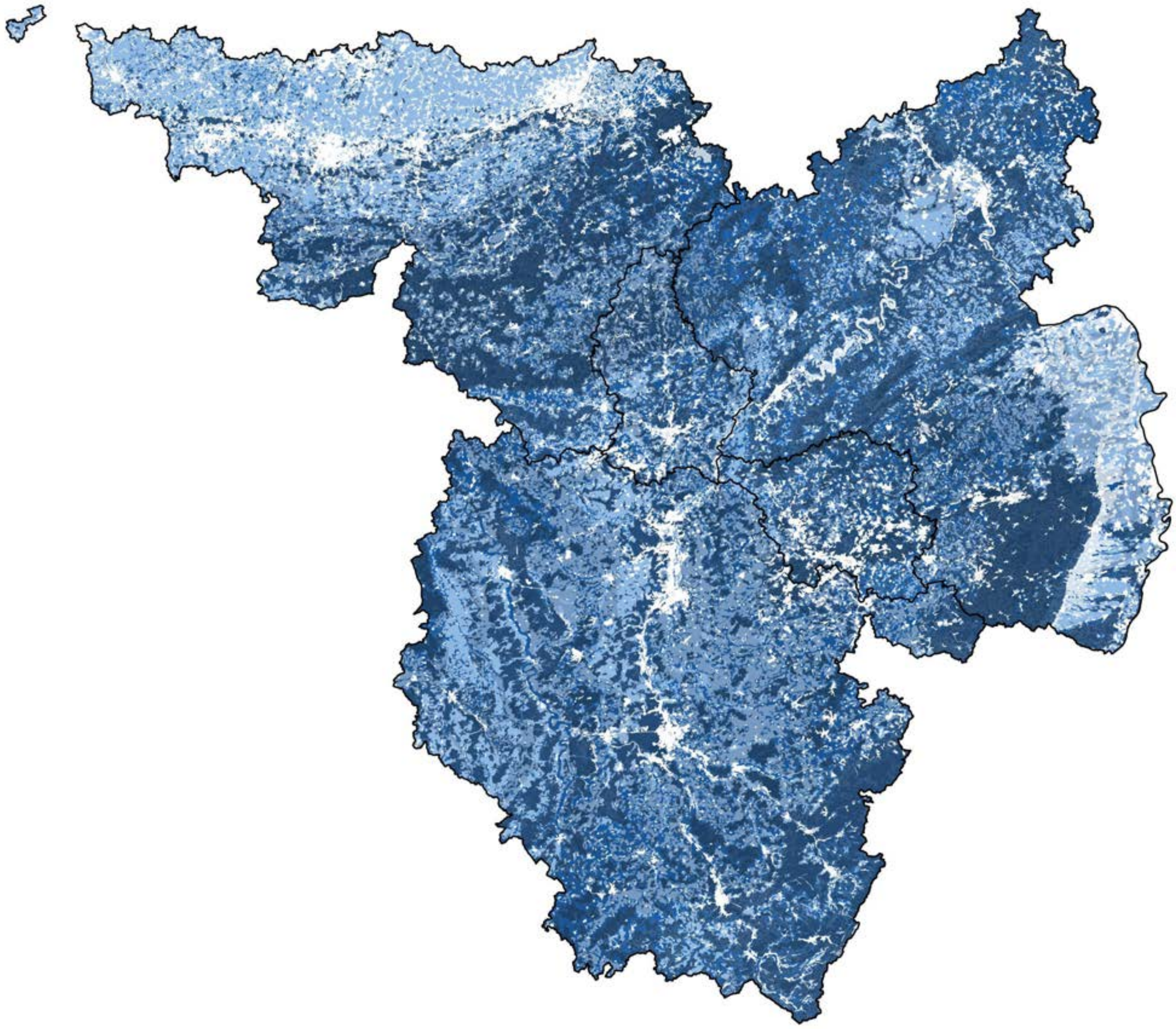


fig. g: Sequestration (impact accumulation 2020 -2050 GRLU)

3.7 2050, enhanced carbon sink

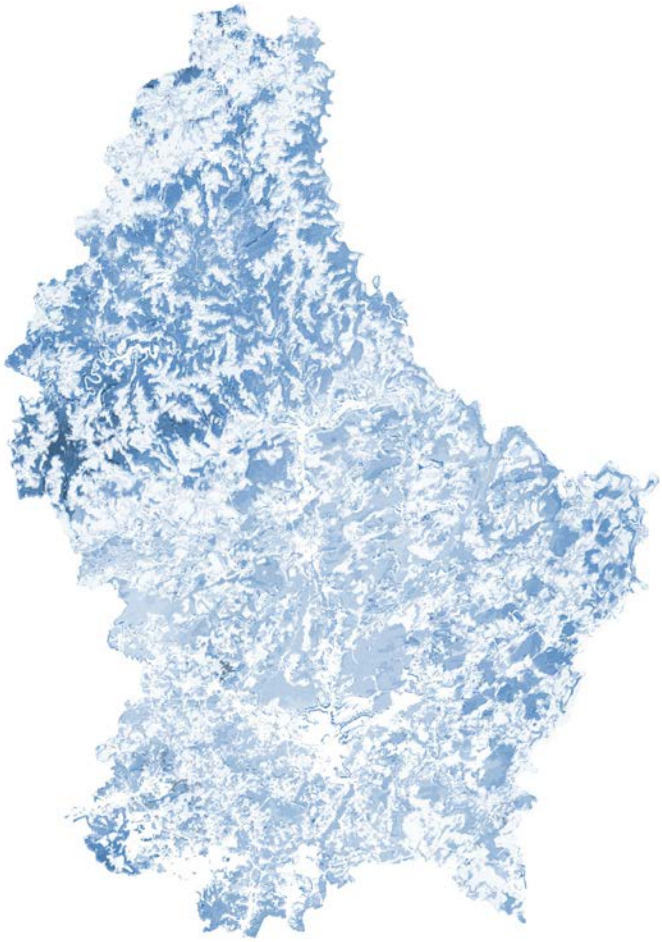
The GRLU territory has the potential to sequester 729 MtCO2-eq by 2050.

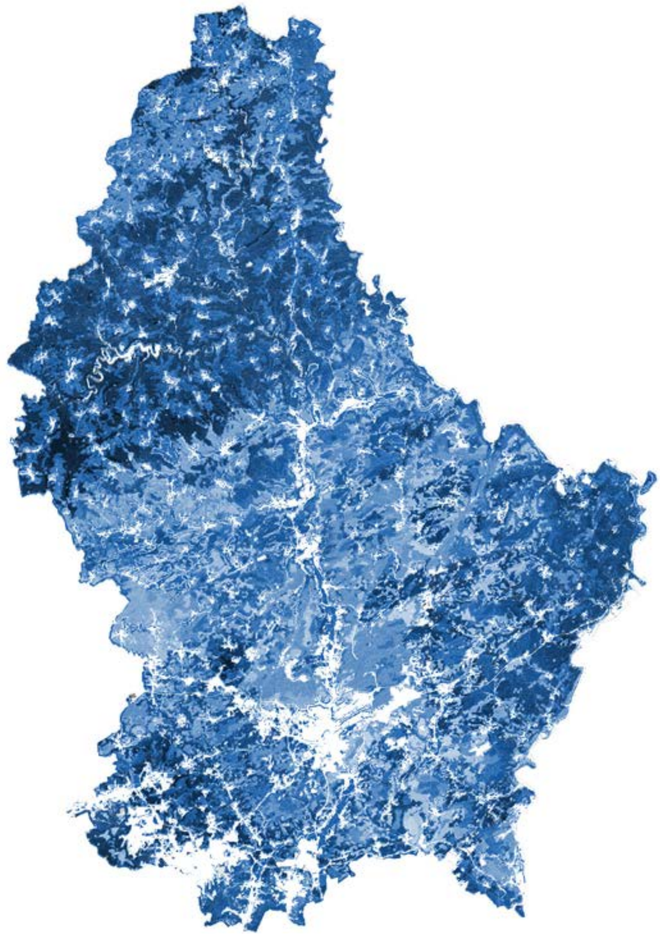


50-70 t C/ha | 100-120 t C/ha | 120-140 t C/ha | 180-200 t C/ha | 200-220 t C/ha | 220-240 t C/ha

3.8 Luxembourg territory, 2020 to 2050

The LU territory alone can sequester more than 18.9 MtCO2-eq by 2050.





50-70 t C/ha 100-120 t C/ha 120-140 t C/ha 180-200 t C/ha 200-220 t C/ha 220-240 t C/ha

3.9 An agricultural revolution

Increased SOC levels as a result of the proposed sequestration tools make the agricultural sector more resilient towards seasonal precipitation and temperature changes as higher organic matter levels in soils act as a sponge retaining water. Hedges and cover crops fixate soils by limiting erosion and runoff during peak rain events. Resulting in more time for infiltration and recharge of groundwater as well as lowering flooding issues downstream due to water retention and slow release. More generalised knock-on effects of carbon sink strategies by ecosystem services result in both social and biodiversity benefits.

Increased soil fertility limits the need for fertilizers and negative effects on bird and other animal populations. Increases in hedges and trees offer more nesting and foraging locations for bird populations, providing natural pest control of crops and reducing the need for pesticides. Both reductions in nitrates and pesticide will reduce the risk of groundwater contamination of Luxembourg`s water resources. In addition, a network of hedges creates more ecological connectivity between isolated habitats.

However, to cope with accelerated climate change, the agricultural revolution needs to move beyond carbon sink strategies. Technology advancements, especially in the fields of crop monitoring, precision agriculture, selection and genetic calibration of species, will be needed to address some of the greater challenges of the coming decades.

Annual precipitation is one of the most fundamental climatic conditions for rain-fed agriculture systems such as those in the Greater region. A gain or a decrease in annual precipitation over the coming decades could determine if certain crops or farm practices remain viable.
A substantial redistribution of seasonal precipitation totals can be expected in the second half of the century, with a decrease in summer rainfall and an increase in winter precipitation. In winter, a 0-25% increase in rainfall is expected by 2050 with increasing discharges. In summer, A 5-25% decrease in rainfall is expected from with reduced run-off by 2050. [22]There is a significant increase in the number of consecutive dry days in Luxembourg based on RCP 8.5 projections: from 13 days median and 15 days maximum in 2020, 17 days median and 24 days maximum in 2051 to 19 days median and 26 days maximum in 2093. [23]

A “dry day” is a day without any agriculturally meaningful rainfall, which is generally defined by a threshold of 0.1 mm/day. The maximum number of consecutive dry days is an important metric for rain-fed agriculture as it directly impacts soil moisture, and thus crop growth. [24] The trend toward more consecutive dry days and higher temperatures will increase evaporation. Long periods of consecutive days with little or no precipitation can consequently lead to drought. This reduced water availability might require a shift to more drought resistant crops.
Beside changes in water availability, changes in temperature will impact the agricultural sector. The projected Increase in temperature for Luxembourg is from 1 °C to 2.2 °C by 2050, [25] as compared to the period 1960-90 and the annual mean temperature is expected to reach up to 11.6 °C for the period 2071 to 2100. For crops such as wheat, maize and barley, there is a clearly negative response of global yields to increased temperatures. [26] As cereals are the main produced and exported crops in Luxembourg shifts to climate resistant crops might be required. [27]

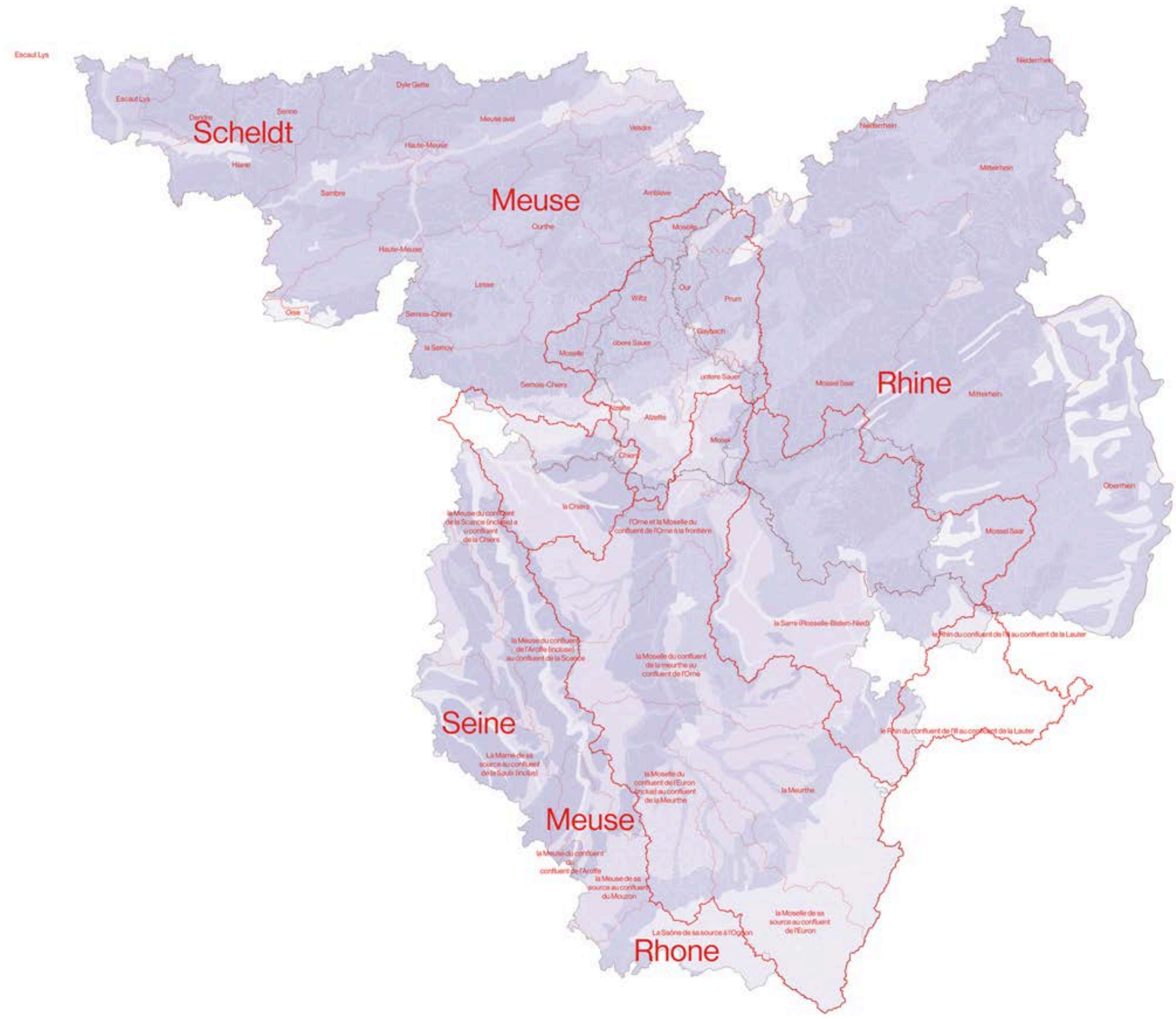
The agricultural revolution needed to adapt to accelerated climate change is about more than carbon sink strategies.


watershed
as new border
Germany
Germany
Luxembourg

REIMAGINING THE TERRITORY

4.1 A bioregional hypothesis

We believe in natural boundaries, rather than political boundaries, to organise communities around resources. Local watersheds can act as an alternative unit for zoning and proximity. Watersheds provide a framework for integrating different land-use and livelihood systems, using water as the "entry point" in the design of interventions.



- search area Cross-border Watershed managment based on European River Catchments (ERC)
- current watershed delineation used by each region
- political borders

Subsoil available water capacity:

very low (0 mm(m) low (<100 mm/m) medium (100-140 mm/m) high (140-190 mm/m) very high (>190 mm/m)

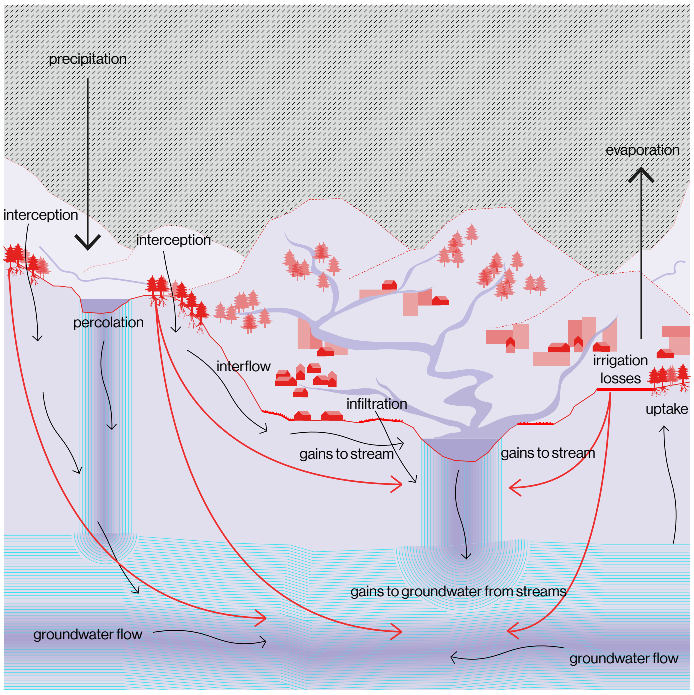
4.1 A bioregional hypothesis

Natural resources are under increasing pressure. By considering all the natural resources related directly or indirectly to watersheds, especially water, land and soil, watershed management provides a framework to assess the ways in which those resources could be used, what affects them, and how they can best be used and protected. Watershed management promotes the adoption of sustainable land and water management practices and encourages investment in better land husbandry that supports, not harms, the ecosystems on which productivity depends. [28] Efforts to improve efficiency in the use of natural resources, especially water, are required to reduce pressures on the natural resource base and to restore the health and quality of freshwater ecosystems.

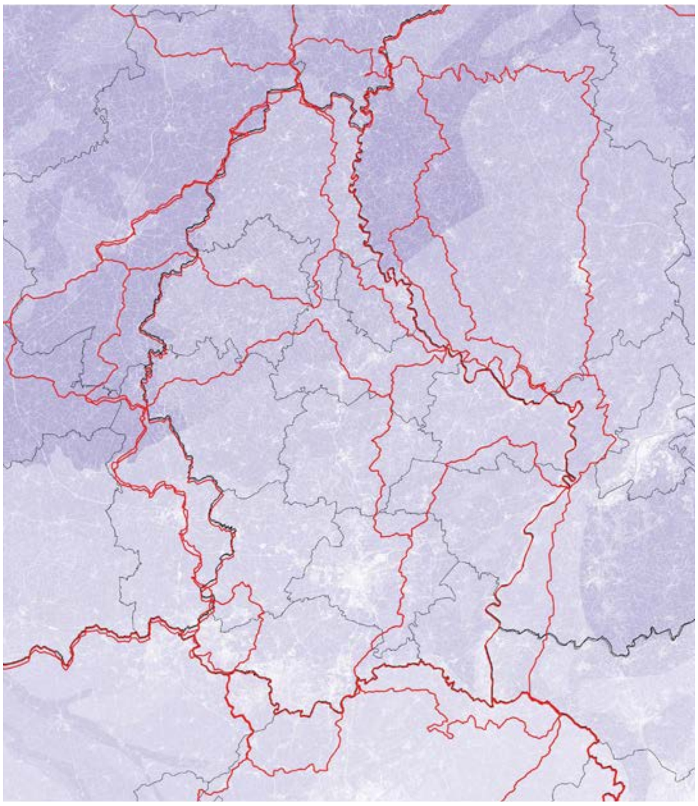
Sandstones, shales and marls sit next to each other in neighboring catchments. Not unlike sponges with very different properties, sandstones can store an enormous amount of water, whereas very tight rocks like marl are almost impermeable to water. [29] Consequently, the underground water storage varies considerably from watershed to watershed. In order to understand how landscapes are going to respond to different climates, it is important to understand watershed storage and release of water through the lens of these different rock types. When it comes to sustainable management of water resources, it is essential to take into account not only the stream flow, but also the groundwater. [30]

The key purpose of watershed management is to negotiate a balance among the interests and often competing needs of stakeholders and to jointly identify options for resource use that balance economic, social and environmental objectives and for which the highest consensus can be achieved among stakeholders. Effective watershed management identifies degraded areas in need of restoration, as well as areas with high ecological value that must be protected from degradation or conversion to other uses. [31]

Watersheds have long been recognized as an appropriate spatial unit for management, and they are also increasingly recognized as the key scale for resource governance. It provides a framework for integrating different land-use and livelihood systems (e.g. forestry, pasture and agriculture), using water as the “entry point” in the design of interventions. [32]

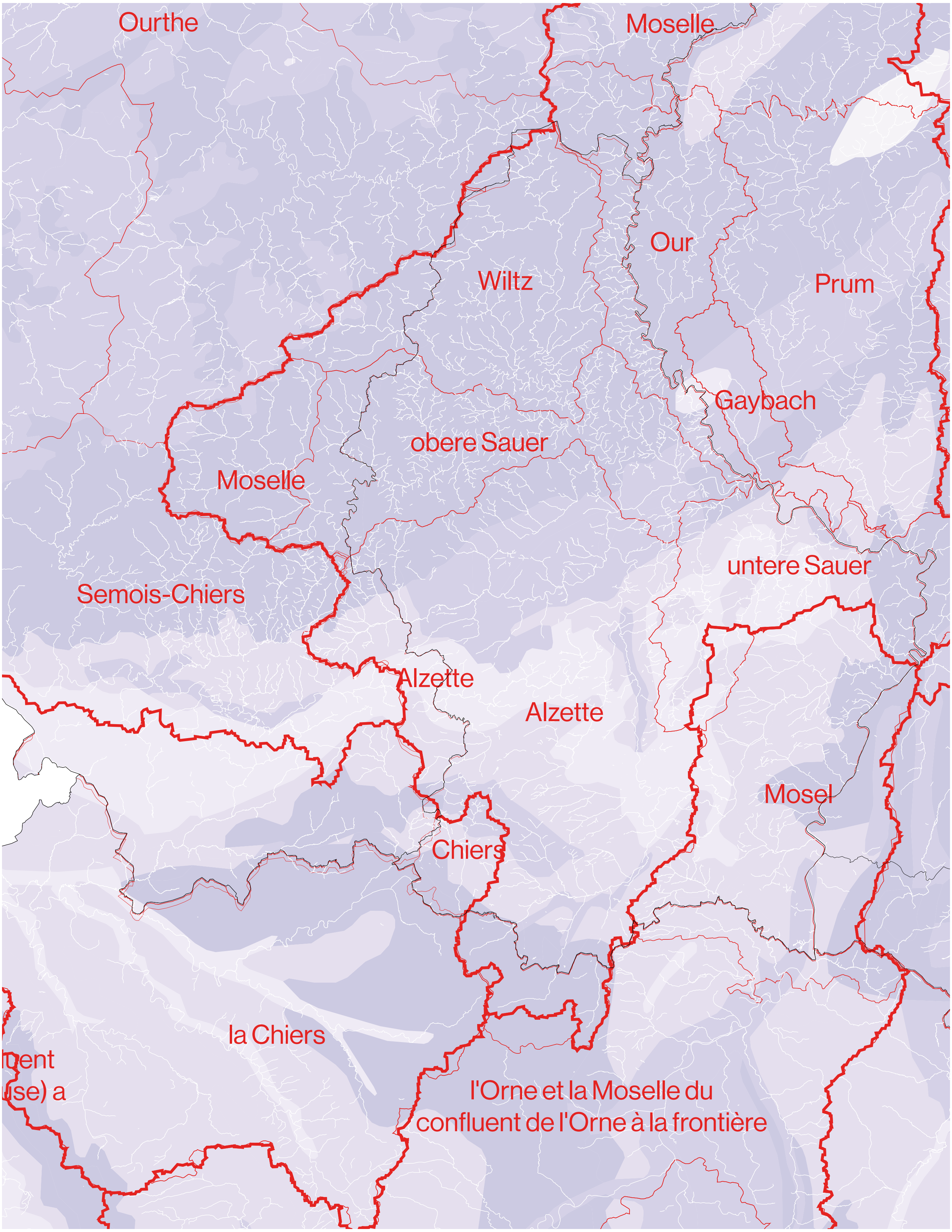


Flows and cycles of water within a watershed. Our forests, farms, lakes, rivers and freshwater sources all depend on the health of our watersheds.



Watershed borders and regional borders within the functional territory of Luxembourg. Settlements can be seen in white.

4.1 A bioregional hypothesis



4.1 A bioregional hypothesis

We imagine a more compact and decentralised socio-spatial structure, whereby resources close to each community can provide for most of its demands. We imagine local watersheds as a form of parallel territorial structure, to organise our communities around. Urban and suburban developments will be denser, as land is treated more as a resource and less as a commodity. With homes and workplaces closer to each other, existing community centres will play a much stronger role in the daily lives of inhabitants. Towns and villages will not need to travel to neighboring cities for daily shopping as the local produce will be distributed frequently for all communities. Car ownership will drop as the need for long commutes reduces across the territory, while on-demand car sharing will rise together with enhanced public transport. This in turn will decrease the demand for parking spots as well.

When land use becomes more dependent on soil, water availability and quality, as well as risks of flooding and drought become paramount. Water systems, structure such conditions, and they are built up by watersheds. Within a watershed, cause and effect are linked. The effect of interference on the water system can be measured within the watershed. When transforming the landscape toward more soil-based complexes, watersheds are the appropriate territorial entity by which this transformation can be organised.

Wholesome decentralisation rests at the centre of the social transition, and the consumption patterns of citizens forms the backbone of meaningful change. Beyond the topic of dietary shift covered in the chapter before, implementing this vision requires innovative densities, proximity of daily destinations resulting in an overall “closeness”. Ownership models play a key role in this redefinition of territorial distances, especially in cross-border and rural environments.

Regenerative agriculture acts as a pillar for the economy of this transition. As we begin to structure our communities around our natural resources, we can imagine to gradually move towards a regenerative territory that is food independent. We can harvest our required construction and insulation materials locally and export the technologies developed in this transition, including monitoring of crops and genetic modification of species, beyond the borders of the functional region.

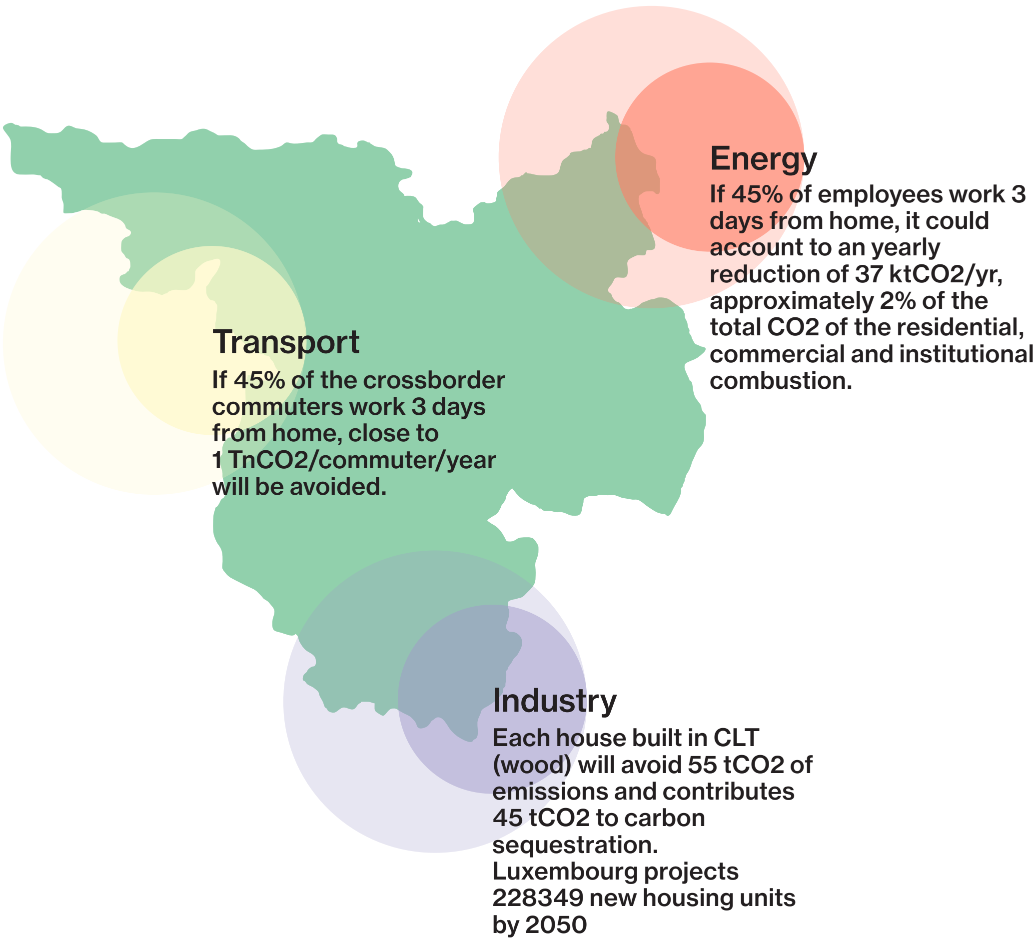
image 13: a visionary leap with embedded historic roots.

image 14: Hyperspectral Imagers closely monitoring growth of crops.

4.2 Implications for other sectors

Potential implication that spring from our bioregional vision on the decarbonisation of other sectors are to be developed in second and third phases in collaboration other teams in Luxembourg in Transition. Based on our conversations during the first phase with our experts, we have listed below a series of tools and metrics to investigate and have begun testing some of these assumptions in this chapter.

1. 45% work from home 3 days a week
2. Reduce car ownership by shared rides
3. Innovative housing especially in suburban and rural communities to expand the affordable housing availabilities
4. Smaller more scattered office spaces
5. Incentives for purchasing local and ecofriendly food and commodities



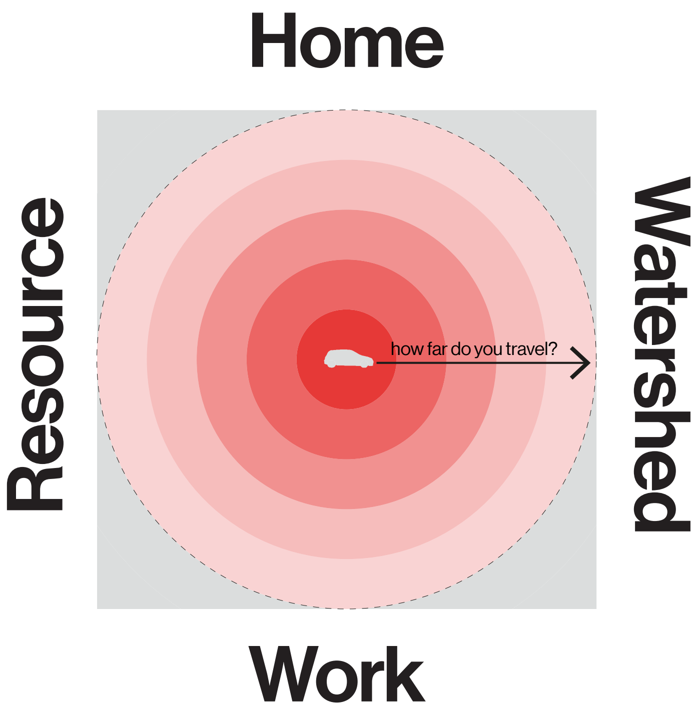
4.3 Reimagining transport

Affordable housing should be reachable within 15 minutes by foot, bike or public transport in order to reduce the need to use private cars. Reducing car ownership rates, will reduce parking demand resulting in gradually freeing up parking structures for other functions including community hub, co-working space and affordable housing. The new urban polarities can be identified based on the overlap of the local watersheds with the existing transport infrastructure, followed by densifying services including jobs, food, recreation, green space, medical offices and small businesses.

For long commutes, the new densified neighborhood's public transport infrastructure, such as rail or bus networks, should be improved and e-mobility hubs should be provided at strategic locations to offer micro-mobility (bike, e-bike, moped, scooter), in addition to charging stations and electric car sharing services. Every shared vehicle can replace up to 11 privately owned vehicles. [33] Special offers for employees, university students, off-peak discounts for young people, women, etc. could accelerate the use of car sharing.

Flexible working policies to allow people to work from home could be followed up with decentralised co-working spaces, especially in active territorial borders and main transit stops. E-mobility P+R close to the border could also shift to green vehicles for people coming from neighboring cities that do not yet benefit from public transport.

The challenge of urban freight is also one that needs a detailed outlook. Following the exponential growth of e-commerce in Luxembourg during the past years, [34] it is essential to invest in optimized urban delivery. We need to provide strategies for green delivery vehicles especially for last mile deliveries, delivery hubs in neighborhoods and areas with higher footfall, consolidation centers close to main urban cores and micro-delivery centers in dense urban areas.

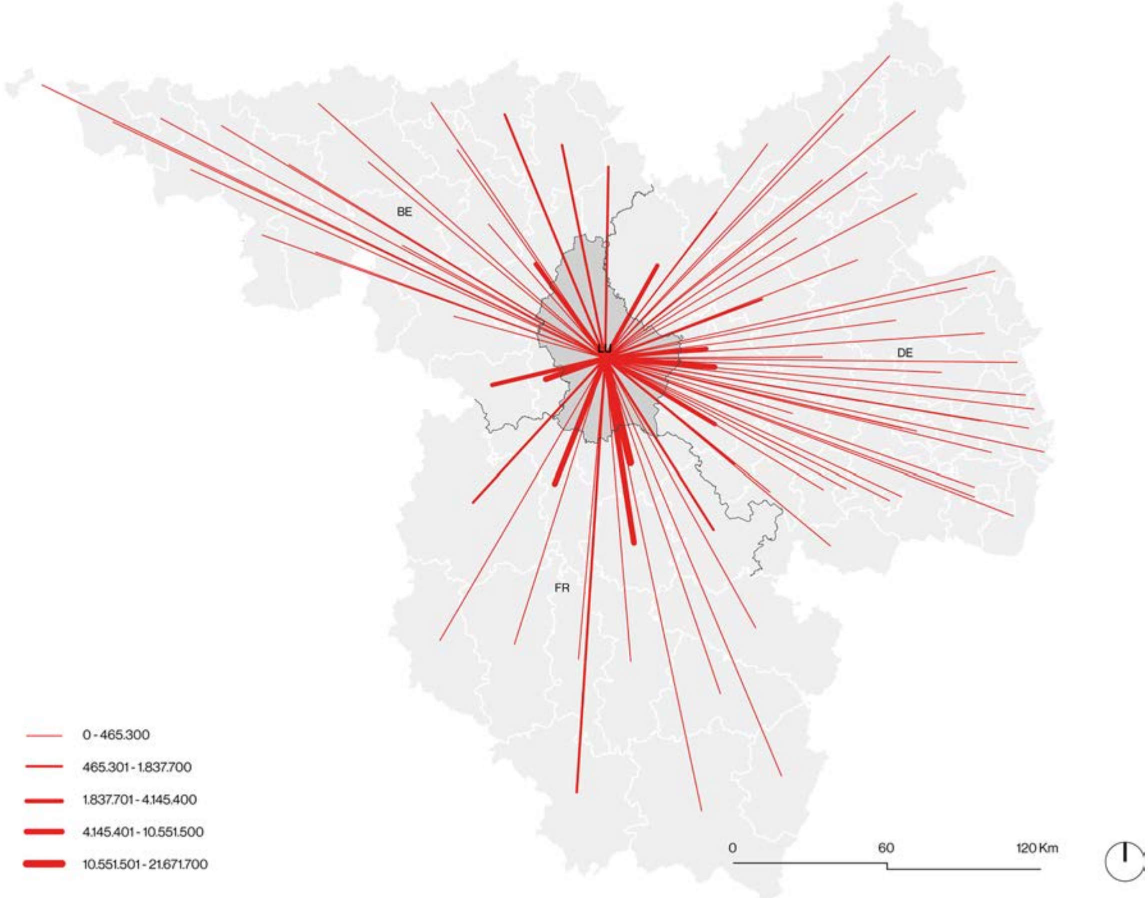


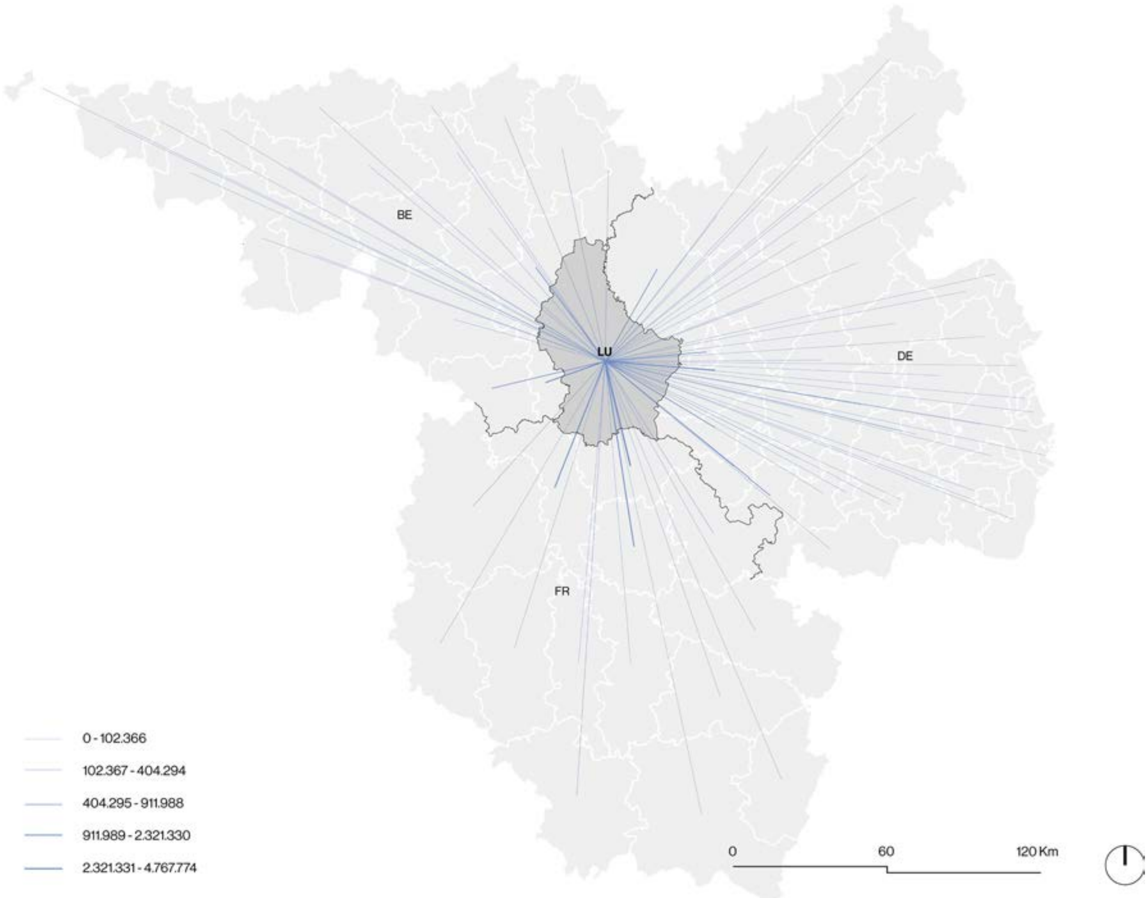
What if we could reach all our necessary destinations within our local watershed perimeter?

We have identified the key performance indicators below to examine the impact of the shifts discussed in the coming phases:

- 15-minute city and remote work: Km travelled per capita 2020 vs Km travelled per capita 2050
- Effectiveness of Public Transport strategies: modal shift 2020 vs modal shift 2050
- 15-minute city, remote work and effectiveness of Public Transport strategies: car ownership rates 2020 vs car ownership rates 2050
- 15-minute city and 15-minute city, remote work and effectiveness of Public Transport strategies: parking demand 2020 vs parking demand of 2050
- Incentives for green vehicles: percentage of electric passenger cars 2020 vs percentage of electric passenger cars 2050.
- Car sharing network and e-mobility hub: number of subscriptions in car sharing network 2020 vs number of subscriptions in car sharing network 2050
- Car sharing network and e-mobility hub: Km travelled per capita by car sharing 2020 vs Km travelled per capita by car sharing 2050
- Optimized urban freight: number of heavy vehicles 2020 vs number of heavy vehicles 2050
- Optimized urban freight: number of green delivery vehicles 2020 vs number of green delivery vehicles 2050
- Optimized urban freight: Km travelled by freight vehicles on the road 2020 vs km travelled by freight vehicles on the road 2050
- Reduced CO2 emissions by moving vehicles (passenger cars and freight vehicles).
- Reduced heat island effect by parking structures.

4.3 Reimagining transport





Projected reduced travel impact of cross-border commuters, assuming 45% of workforce works 60% of the week.

4.3 Reimagining transport

What if:

Flexible working policy for cross border employees

Currently there are 200,000 daily border crossing commuters entering Luxembourg for work. [35] Considering 45% of employees having the possibility of working 3 days a week from home and considering 73% of the trips are done by personal car, and the average distance travelled daily by commuters from France, Belgium, and Germany estimated to be 75 km and car occupancy of 1.23, 1,138,979,08.20 vehicle-Km will be saved per year. Considering the 0.136 Kg of CO2 per Km for passenger cars, the strategy will result in 0.945 tons of CO2 reduction per cross-border commuters per year.

Flexible working policy for national employees

Based on the labor market statistics overview provided by Statistics portal of the Grand-Duchy of Luxembourg, there are currently 272,100 national employees, estimating 90% commute to work on a daily basis. [36] Considering 45% of employees having the possibility of working 3 days a week from home for 47 weeks per year and considering 73% of the trips are done by personal car, and the average distance travelled daily is 26 km and car occupancy of 1.167, 508,476,507.05 vehicle-Km will be saved per year. Considering the 0.136 Kg of CO2 per Km for passenger cars, the strategy will result in 0.295 tons of CO2 reduction per national employee per year.*

*References for tables and calculations can be viewed on page 108 of this dossier

4.3 Reimagining transport

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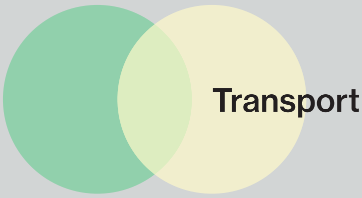


If 45% of the crossborder commuters work 3 days from home, close to 1 TnCO2/commuter/year will be avoided.

4.4 Reimagining energy

The Covid-19 pandemic has brought many important disruptions in the way we live. One of them is the ways and the places we work. This disruption marks the beginning of a new mode of working, and many large firms have already adopted working for home as a standard. To name a few, Siemens [37] and Twitter [38] have already announced a work-from-home plan. If working from home is an option, some alternative office models, such as 'hub and club' or satellite offices will also become part of the discussion.

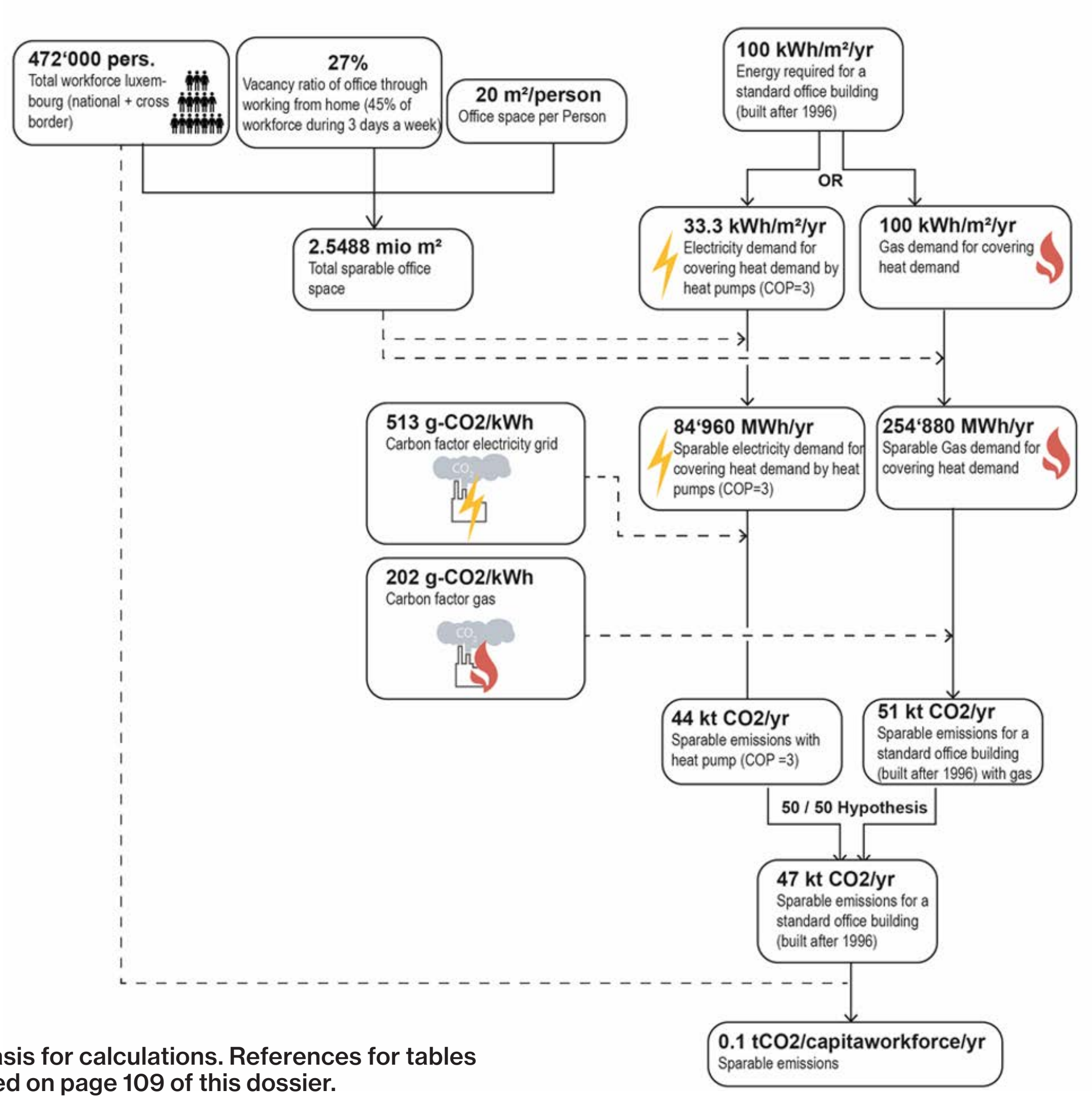
The shift from office work to working from home is expected to have an impact on the surface required per employee in workplaces. In the mid to long term, the office space area needed per person will decrease as firms adapt to employees working from home. In their recent press release, Fujitsu has announced a reduction of 50% in office footprint by FY2022 [39].

Quoting Jess Staley, British investment bank Barclays' CEO: "There will be a long-term adjustment to our location strategy [..] The notion of putting 7000 people in the building may be a thing of the past." [40] The same horizon is shared by the consulting firm JLL, in its report on 'View on the post-COVID real estate office market in Luxembourg' [41]:

"If in the short term a reduction of demand for office space is inevitable, in the long-term demand is unlikely to drop, but strategic changes will require investments in remote working facilities including satellite offices."

What if:

Reducing emissions by reduction in office footprints
Assuming that 45% of the workforce will work 3 days a week from home, the impact for building energy consumption is estimated. It can be assumed that the electricity consumption for working equipment of one person does not significantly change, whether the person works from home or from the office. However, as there is less surface dedicated per person, the space conditioning energy demand decreases. According to a first estimation, this could account to an yearly reduction of 0.1 tCO_2/capitaworkforce/yr (or 37 tCO_2 /yr). This reduction is approximately equivalent to 2% of the total CO_2 of the residential, commercial and institutional combustion of Luxembourg. In order to get a complete picture, the embodied energy savings of building constructions should be added to the calculation.*



* Flowchart presenting the basis for calculations. References for tables and calculations can be viewed on page 109 of this dossier.

4.4 Reimagining energy

1. 45% work from home 3 days a week
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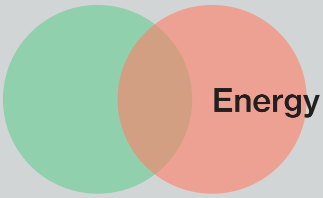

If 45% of employees work 3 days from home, it could account to an yearly reduction of 37 ktCO2/yr, approximately 2% of the total CO2 of the residential, commercial and institutional combustion.

4.5 Reimagining industry

Conventional housing construction depends on carbon intensive materials such as concrete. Luxembourg`s construction sector alone had 200000 tons of CO2-eq in direct emissions and 1000000 CO2-eq in Indirect emissions in 2009.[42] At the same time there are heavy losses of sequestered carbon stock in the forestry sector due to unsustainable wood harvesting that is not decomposed at the end of its lifespan or used as woodfuel (-200 GgC/yr) in Luxembourg. [43]

By shifting the construction sector's method of choice to Cross Laminated Timber (CLT) these two issues can be resolved together. 1 housing unit by conventional cement-based construction has a footprint of 55 tCO2-eq. In contrast, 1 housing unit by CLT construction avoids this 55 tCO2-eq, and contributes to sequestering 45 tCO2-eq by the wood it uses. [44]

For Luxembourg the projected housing demand is estimated on 228349 extra housing units by 2050. [45] Within the Greater Region, there is an expected population growth in Luxembourg (+56%) and Wallonia (+10%) by 2050 but in other regions such Saarland (-22%), Rheinland Pfalz(-12%), Lorraine (-2%) a decrease in population is expected.
What if:

To illustrate the feasibility of such a shift where all the housing units are constructed in CLT, without sourcing wood elsewhere, it would require 66% of the projected harvest-able wood (until 2050) from Luxembourg forests. Also agricultural rest materials can play an important role in biobased construction, supplying materials for insulation and other purposes.
The calculation of the housing demand in Wallonia is based on the ratio between Luxembourg's projected housing demand and projected population growth and what the projected population growth is in Wallonia.

The chart in this page shows the comparison for Luxembourg and Wallonia. The projections for the remaining regions are under investigation and will be presented in the next phase, in addition to going into further detail into the study.

Decarbonisation by shift to CLT from conventional construction (impact accumulation 2020 -2050 Greater Region) Mton CO2-eq

fig. i

4.5 Reimagining industry

1. 45% work from home 3 days a week
2. Reduce car ownership by shared rides
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4. Smaller more scattered office spaces
5. Incentives for purchasing local and ecofriendly food and commodities

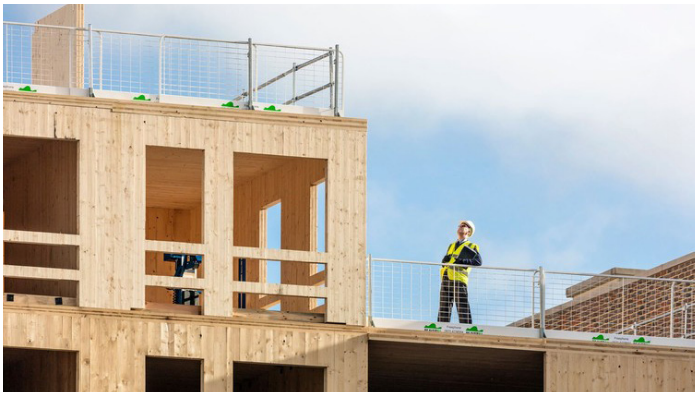
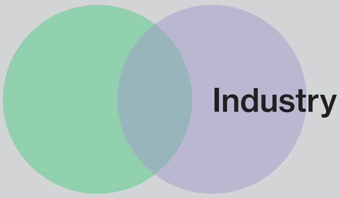


image 15: Harvesting materials, building in CTL (2018)



Each house built in CLT (wood) will avoid 55 tCO_2 of emissions and contributes 45 tCO_2 to carbon sequestration.

Luxembourg projects 228349 new housing units by 2050

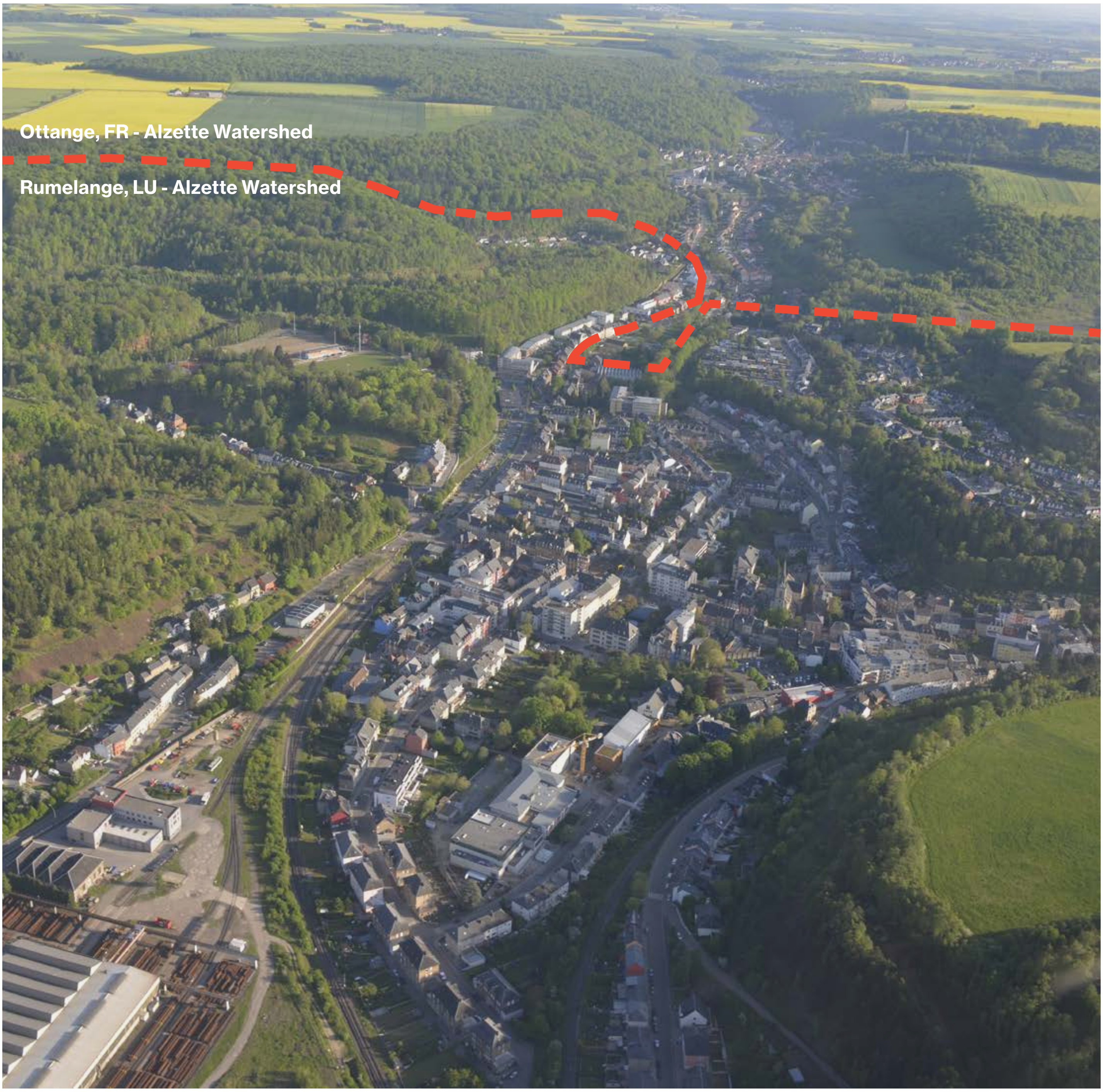
4.6 Next steps

In this first stage we have covered our preliminary vision for the transition of the Greater Region of Luxembourg and tested our proposed tools and metrics in relation to lifestyle changes, land use change and regenerative agricultural practices.

We also began a number of investigations into how our vision could have a decarbonising impact on other sectors. These research streams will continue to be detailed in the upcoming phase and expanded by collaborating with other teams who have been focusing on the relative sectors.

We will continue to build on our research on local initiatives and investigate possible alignments and coalitions among crossborder institutions, businesses and communities. Piecing together the vision framework with the local know-how, we strive towards a territorial project strategy for the Luxembourg cross-border region. We will look further into tools to scale up local initiatives and investigate how small innovations can go ‘viral’.

By facilitating a transborder, multiscalar conversation among neighborhoods and nations we intend to embolden local actions that have global impacts. Adopting a nature and lifestyle based approach would help us steer holistic, evidence-based transition scenarios and provides us with an actional framework for application of spatial visions.



4.7 Vision

1. Agriculture TnCO2-eq/yr

1. Adapted to a balanced diet
2. Plant protein needs considerable less surface area to produced the same amount of kcal(1,3% of the area needed for beef).
3. Increasing yield
4. Converting reclaimed land to forests.

2. Carbon Sinks TnCO2/ha

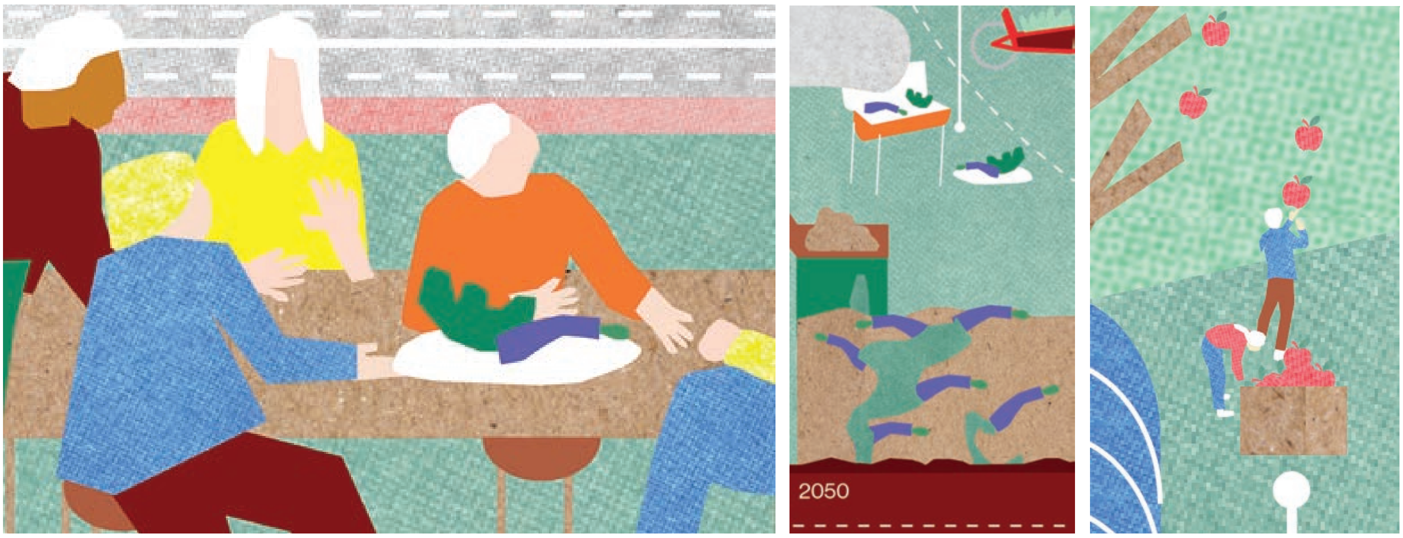
1. Organic matter additions to croplands
2. Zero tillage on croplands
3. Crop covers
4. Hedges on croplands and pastures
5. Alternative forest managment
6. Silvo-pastures

3. Diet Kcal/capita/day

1. Reduction of consumed meat
2. Replacement by plant protein
3. less bovine and pig meat, and more sheep and goat meat
4. A more drastic change towards veganism (50% of population) can reduce GHG even more and free up more land from livestock production and increase the total agricultural yield and/or forest cover greatly.

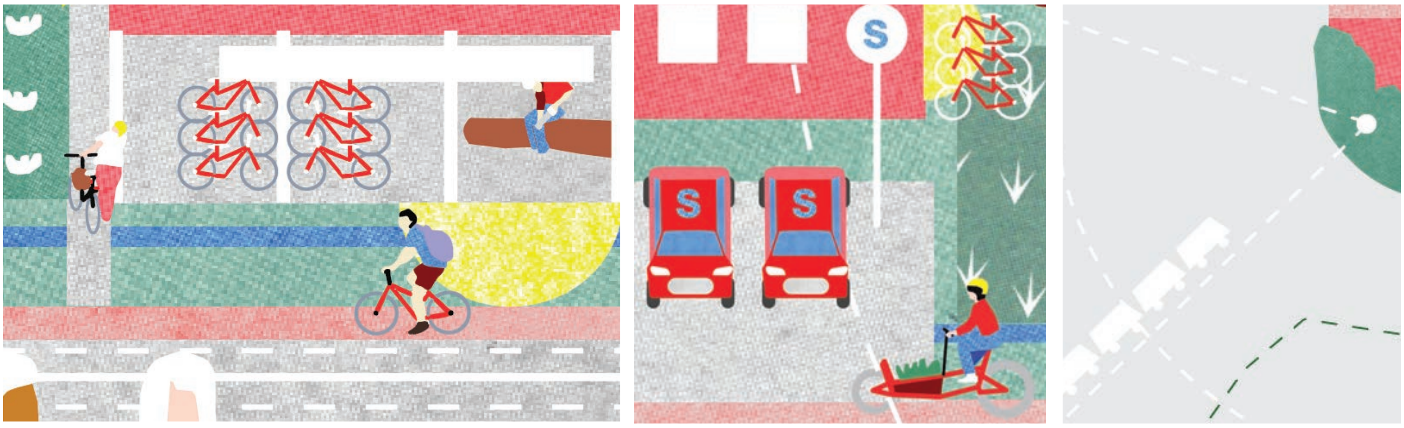
4. Proximity Km/capita/day

1. 45% work from home 60% of the week
2. Reduce car ownership by shared rides
3. Innovative density especially in suburban and rural communities to expand the affordable housing availabilities
4. Implementation of carbon tax on fuel
5. Smaller more scattered office spaces
6. incentives for purchasing local and ecofriendly food and commodities



The citizens discuss the harvest over a good vegetarian barbecue. Fruit production is particularly abundant this year, how should it be distributed?

By cargo bike to local restaurants, offices and outlets. Larger quantities by train. Some of it could be distributed to neighbouring regions.

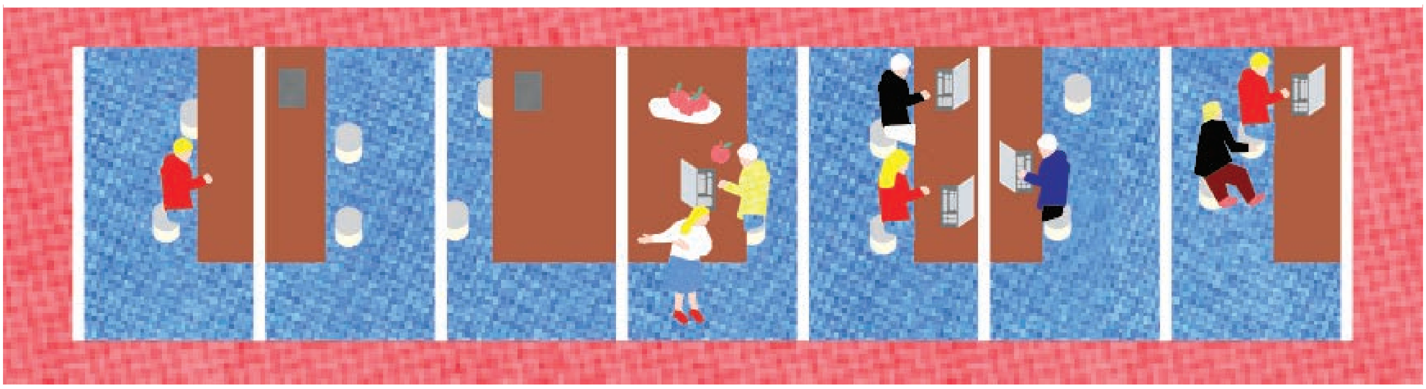


The distribution network is based on a strong network of shared mobility, accessible to everyone. It's much healthier and more active!

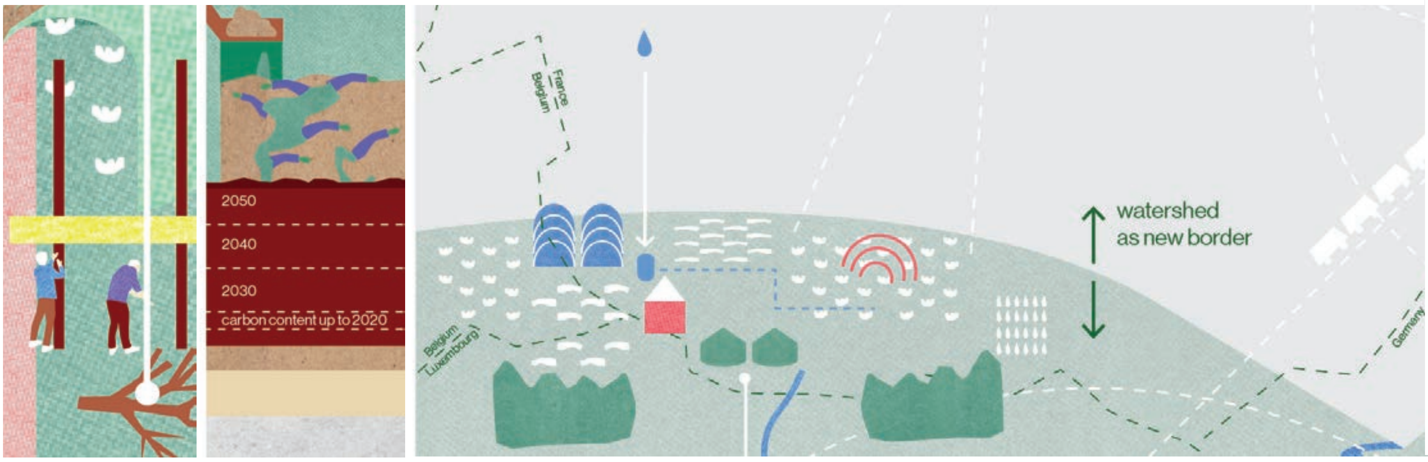
Agriculture makes intelligent use of the watershed. On the plateaus, crops; on the slopes, forests to prevent erosion, in the valley, pastures and collective gardening.

The watershed supports everything we need: wood for building construction, food and other agricultural products. We need to keep a close eye on it with state-of-the-art technology.

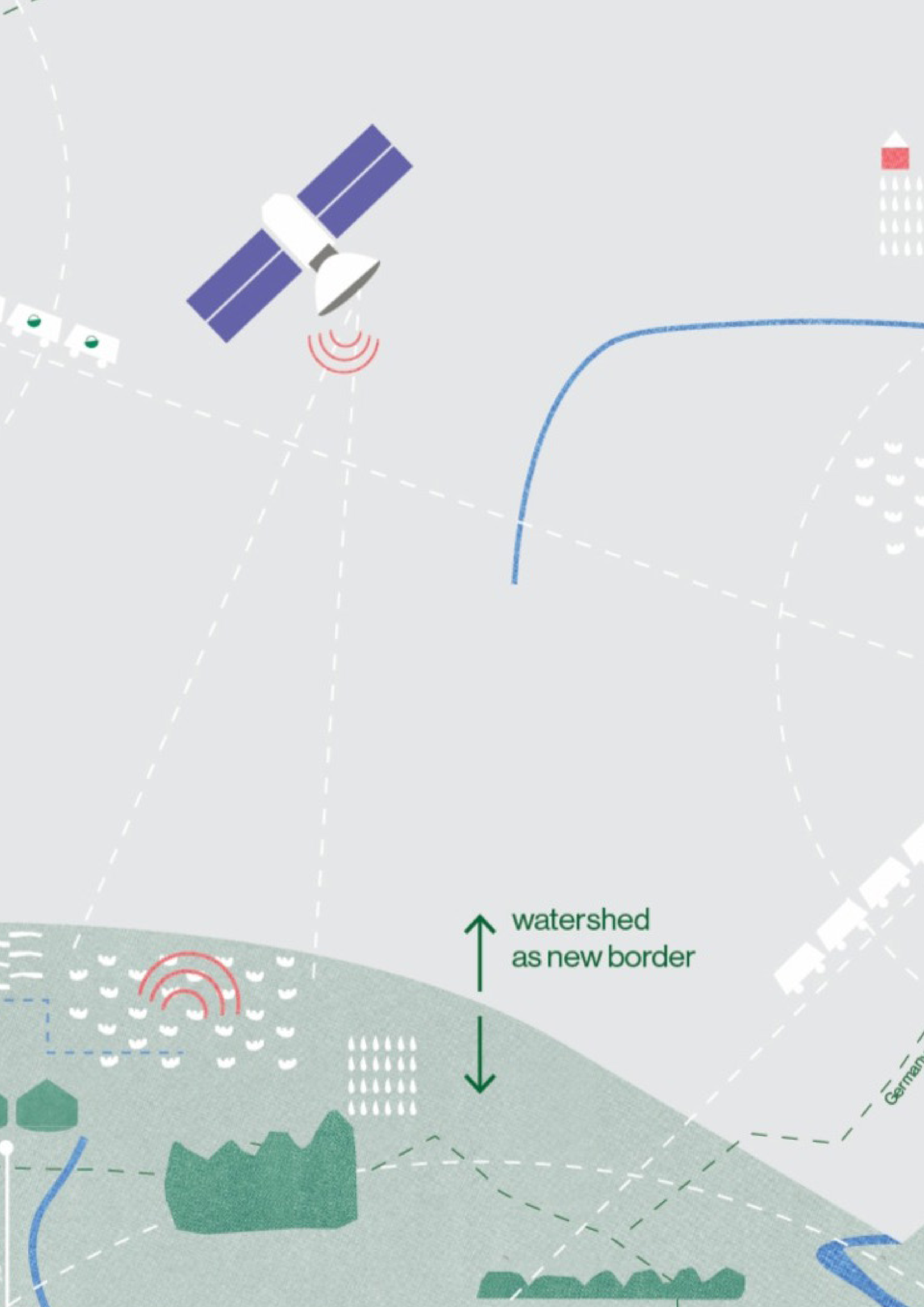
The habitats are denser, but there is a lot of shared green space. Nature is accessible and all community members feel belonged to it and take care of it.



Co-working spaces are available close to our living space. We can easily get there by bike. We also work part of the week from home. We use the car much less.



As our relationship with our land has changed, we have created new models of ownership, to be able to share this resource in more equitable ways. The closeness between destinations and resources, has also strengthened our social bonds.


watershed
as new border

APPENDIX

5.1 Glossary

ACC: Acceleration

ACT: Action

AS: After Shift

BAU: Business As Usual

CLT: Cross Laminated Timber

EC: European Comission

EU: European Union

GRLU: Greater Region of Luxembourg

LU: Luxembourg

LULUCF: Land Use, Land Use Change, and Forestry

UBI: Universal Basic Income

SOC : Soil Organic Carbon

5.2 INITIATIVES

The project-based relational metric embeds within it 3 scales of measurement.

A.1 The role of metrics
A.1.1 Action Metrics
A.1.2 Acceleration Metrics
A.1.3 Evaluation Metrics

A.1.1 Action Metrics

Description: Action metrics describe the current state of being and set a precise desired outcome in the tangible future. They support a common narrative and objectivity and justify the framework or initiative. On a personal – or initiative – scale action metrics push people one step further each time towards an overarching goal.

Example: Soil Matters is a platform that support farmers in the Netherlands, and work with farmers all over the world to learn about healthy soil.
It is strictly connected to the company Farm Brothers, for example. The latter, by donating 5% of turnover, before profits, to farmers transitioning from conventional to regenerative, organic farming, really put money in the ground! They donate to Stichting Groundbeheer, a steward of biodynamic farmland, and their farmers make this all possible. By donating or buying Farm Brothers cookies on Soil Matters website it is possible to make the contribution.
Within this framework of the carbon sink natural strategies, the shift to organic farming is fundamental.
Supporting this shift, the platform is a tangible action toward de-carbonization.

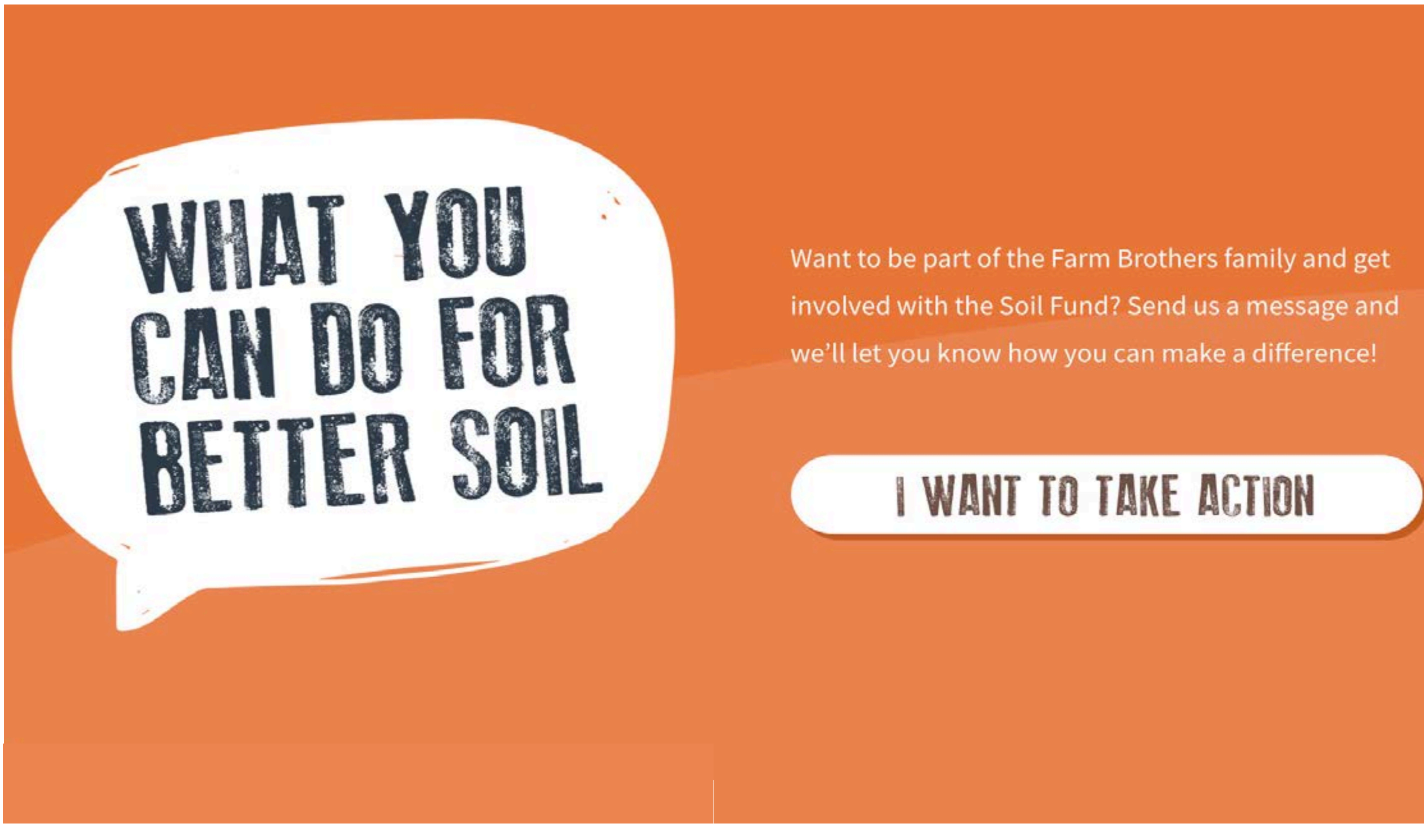


fig. 32: Soil Matter website, ban to take action.

A.1.2 Acceleration Metrics

Description: Acceleration metrics stimulate initiative to broaden their scope or to be more present, and in that way multiply their impact and raise more awareness. There is no single formula for success for an initiative to go viral or to increase their impact exponentially. New collaborations are a crucial part in this, as well as triggering new target audiences, exploring a multitude of different options and walking many trails.

Example: The Sustainable Development Goals of the United Nations are the goals that the world has set by 2030 to work on sustainable development. The shared 17 main objectives and 169 sub-objectives form the most important international sustainability framework for the next 10 years.
The power of the SDG framework is in their wide range from worldwide goals, targets and measurable indicators to their translation to the smallest level of regions or municipalities. There the framework is transformed to a backbone for activities, personal engagement, tools, and trigger acceleration through widely supported and commonly accepted values.
In the current pandemic the SDG framework becomes more than a target and also describes what is at risk. The revised manifesto reads as call to save the progress that was made in the last 15 years.

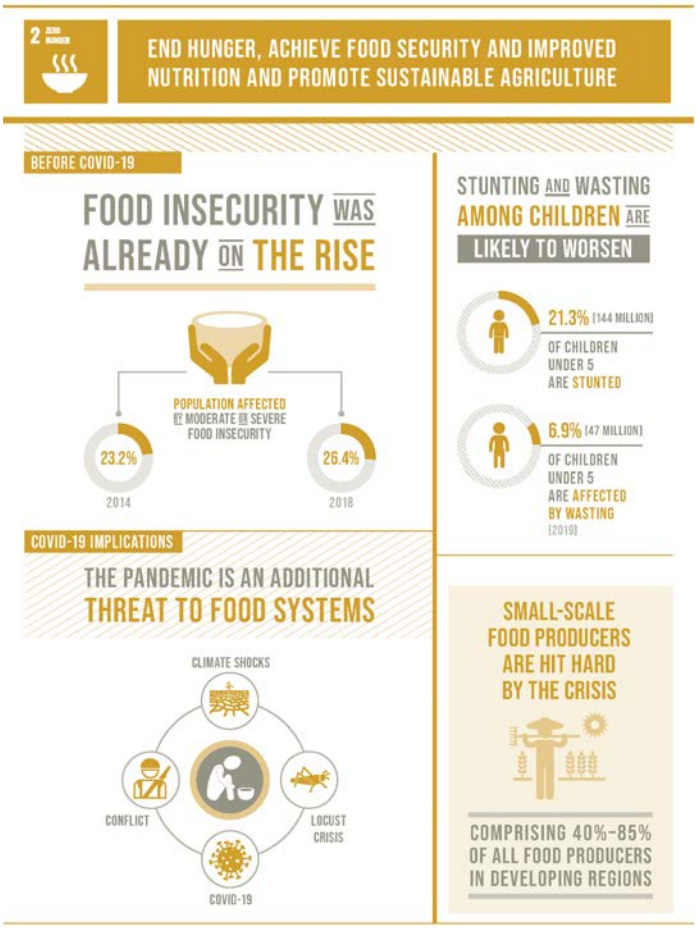


fig. 33

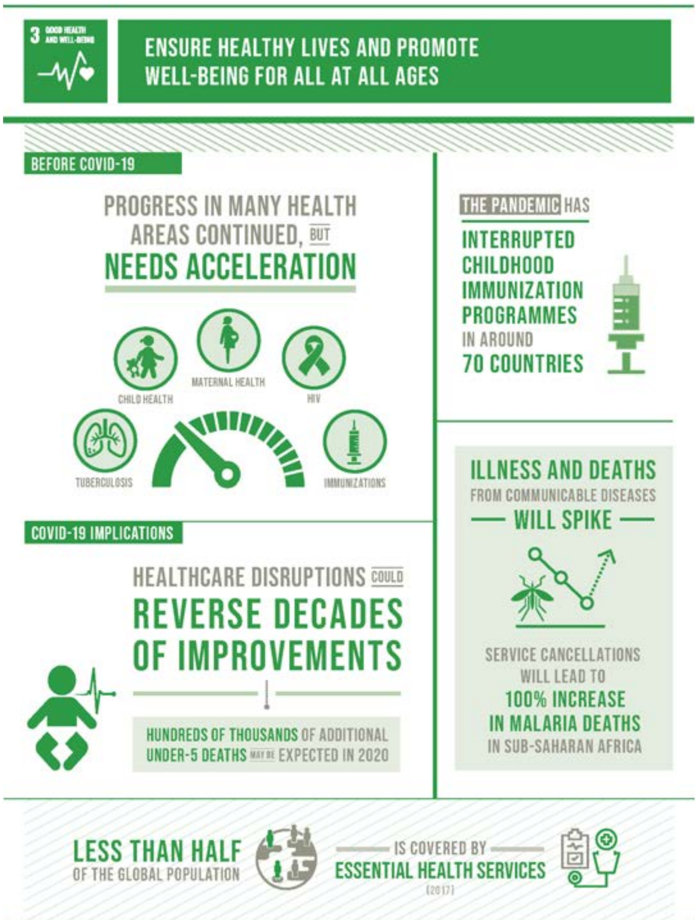


fig. 34

A.1.3 Evaluation Metrics

Description: Political institutions must choose a measurement framework by which they can evaluate the growth and prosperity. These frameworks influence policy decisions and the structure of our economies and as a result collective behaviour and ideology. They are a way of measuring governmental impact, monitoring progress and giving a quality injection when needed.
We need an alternative to GDP, where the wellbeing of ecosystems and species is taken into consideration as part of the definition of prosperity. It is only then that the true costs, and benefits of climate mitigating and adapting practices will come to light.

Example: (GNH) is a method for measuring quality of life in a different way. The framework is based on four principles: (1) promoting fair and sustainable socio-economic development; (2) preservation and promotion of cultural values; (3) preservation of the natural environment and (4) good corporate governance.
In Bhutan, the only country in the world that adopted GNH instead of GNI, national happiness is measured by a holistic survey considering a wide range of factors. The reason this framework works for a country as Bhutan, much more than its implementation in planning projects, is because citizens have ownership over the topic. The framework is a narrative that is backed-up by a measurement system, not the other way around. The country is collectively defining what metrics work and indicate their personal growth and are in that way a reflection of values, much more than just persuadable goals. That said, it works better in certain sectors, and especially the spatial execution is challenging because it's hard to translate into the right parameters. For more holistic policy decisions on a national level, like evaluating a legal bill, this system again works perfectly.

fig. 35

5.2 Initiatives

A.2.1 ACT: InnovaFeed (FR)

Summary of initiative: InnovaFeed is a company that focusses on insects as becoming keystone of future food systems. It's a pioneer in the construction of new agro-industrial sector based on insect breeding. They use local resources to feed their insects and use the insect's frass as organic fertilizer to work on a circular and zero waste approach. This way of producing insects enables high quality protein in a sustainable way, perfect to support the growth of the aquaculture.

Actors involved: Auchan (insect-fed trout in French supermarket), Tereos, Mr Goodfish, Creadev & Temasek, Nealia. [46]

Condition that they tackled: environmental impact of aquaculture

Impact: Currently InnovaFeed has one production site and one under construction. The Nesle Site (a partnership between InnovaFeed and Tereos) will secure plant-based agricultural by-products as feed for breeding its insects. By integrating their industrial processes, the two companies are also contributing to minimizing the impact on climate change. The operation of this unit will specifically enable the avoidance of 25,000 tons of CO2 per year. [47]

image 17: Innovafeed company

A.2.2 ACT: 4000 km of hedges (Wallonia)

Summary of initiative: The Walloon coalition agreement of 2019-2024 states that 4000 km of new hedges will be created to enhance biodiversity. Hedges are a structuring element of landscapes and play an important role as a refuge and ecological corridor for wildlife. Hedges create additional habitat for certain animals. In addition, hedges can help connecting fragmented nature and serve as a kind of highway for animals. There are also advantages for insects, because the wood edges also contain species with flowers. Hedges are good at retaining water in the soil, helping against fertilizer pollution and soil erosion.

Actors involved: department of environment of Wallonia, Walloon Farmers and landowners. [48]

Condition that they tackled: The lack of biodiversity in rural areas and the fragmentation of nature areas.

Definition of tool: Grant subsidies (1 million euro/year, gradually rising up untill 2 million a year in 2024) for the planting of hedges.

Impact: Since the coalition agreement was concluded in 2019, 45 km of hedges, 1.7 km of undergrowth, 800 row trees and 1,900 fruit trees (belga) have already been planted. [49]

image 18: 4.000 km hedge in Wallonia.

A.2.3 ACC: De Land Genoten (BE)

Summary: De Landgenoten is a Belgian coöperative foundation who buys farmland with the money of shareholders and donors, to then use these lands as commons for a more sustainable food production. The lands are rented to bio-farmers through long term leases in order to increase the offer of local, biological and healthy food. The foundation also manages lands of owners, and stimulates these to let their plots be cultivated in a sustainable way.

Actors involved/coalitions: The cooperation is founded by multiple local and regional civil society organizations such as natuurpunt, Oxfam but also some CSA-farms and interest groups. It got sponsored and subsidised by a number of parties, and uses private investors interested in sustainable entrepreneurship as well.

Founders: Vlaanderen BioFoum, CSA-netwerk, De Wassende Maan, FIAN, Hefboom, de Kollebloem, de Landwijze, Bond Beter Leefmilieu, Land-in-zicht, Natuurpunt, Oxfam, Terre de Liens, Terre-en-vue, Velt and more

Sponsors: Apple for the brain, BioForum Flanders, Flanders circular, European agriculture foundation for rural development, and more

Condition they tackled: Prizes of farmlands are increasing heavily in Flanders the last decade and the average age of farmers is getter close to 65. In order to give young farmers a chance in agriculture, where nowadays more and more needs to be produces for less and less incomes, the foundation tries to supply an amount of affordable lands. By doing this, they also conduct these farmers in flood prevention, bettering the quality of the soil, and the biodiversity of their grounds. [50]

Definition of the tool: collectively invest in farmlands to use them as commons for sustainable agriculture. When enthousiast farmers have a land in mind, they can crowdfund the needed amount via shareholders of De Landgenoten.

Impact: Currently over 17 ha of farmlands have been purchased for 6 projects situated in Flanders, and another 18 ha is being crowdfunded for 3 additional projects. In a next phase this kind of initiatives can be scaled-up (like the simmilar Dutch Stichting Grondbeheer with 250 ha and French coöperation Terre de Liens, with 5 500 ha of farmlands and 207 farms). [51]

image 19: De Landgenoten facebook image.

5.2 Initiatives

A.3 Carbon Sink

A.3.1 Volonteer planters (FR)
A.3.2 4 per 1000 (INT)
A.3.3 Proeftuin ontharden (BE)

A.3.1 Volonteer planters (FR)

Summary of initiative: Volunteer planters is a reforestation organisation that works through civil projects, carried with broad consultation with local stakeholders and strong participation of the inhabitants. This happens while mobilising a big group of people (inhabitants, students, employees, people with disabilities, economic or social exclusion, prisoners, ...).

Actors involved: Foundation de France, la Foundation de Lille, Region Hauts-de-France, AFAC, MEL (metropole de Lille),... (http://planteurs-volontaires.com/nos-partenaires/)

Condition that they tackled: deforestation, soil- and biodiversity degradation

Impact: 192 locations since 2013, 8000 participants and 134000 trees planted. The objective is for 18 000 new plated trees a year. Most common calculations happen with a lifespan of 20 years and 20 kg of CO_2/year wich gives a total of 7 200 ton CO_2 annually. [52]

image 20: Volonteer planters in action.

A.3.2 4 per 1000 (INT)

Summary of initiative: this initiative was launched at the COP21 in Paris 2015. It attempts to unite all voluntary stakeholders from public and private society and has as purpose to stress that (agricultural) soil plays an important role when it comes to food security and climate change.

Actors involved: actors and organisations from all over the world, going from governments to enterprises, NGO's, etc.

Impact: the purpose is an annual growth rate of 0.4% in the soil carbon stocks in the first 30-40cm of the soil. By doing this, the CO2 concentration would significantly reduce. This can be done by reducing the deforestation, and encourage agro-ecological practices. [53]

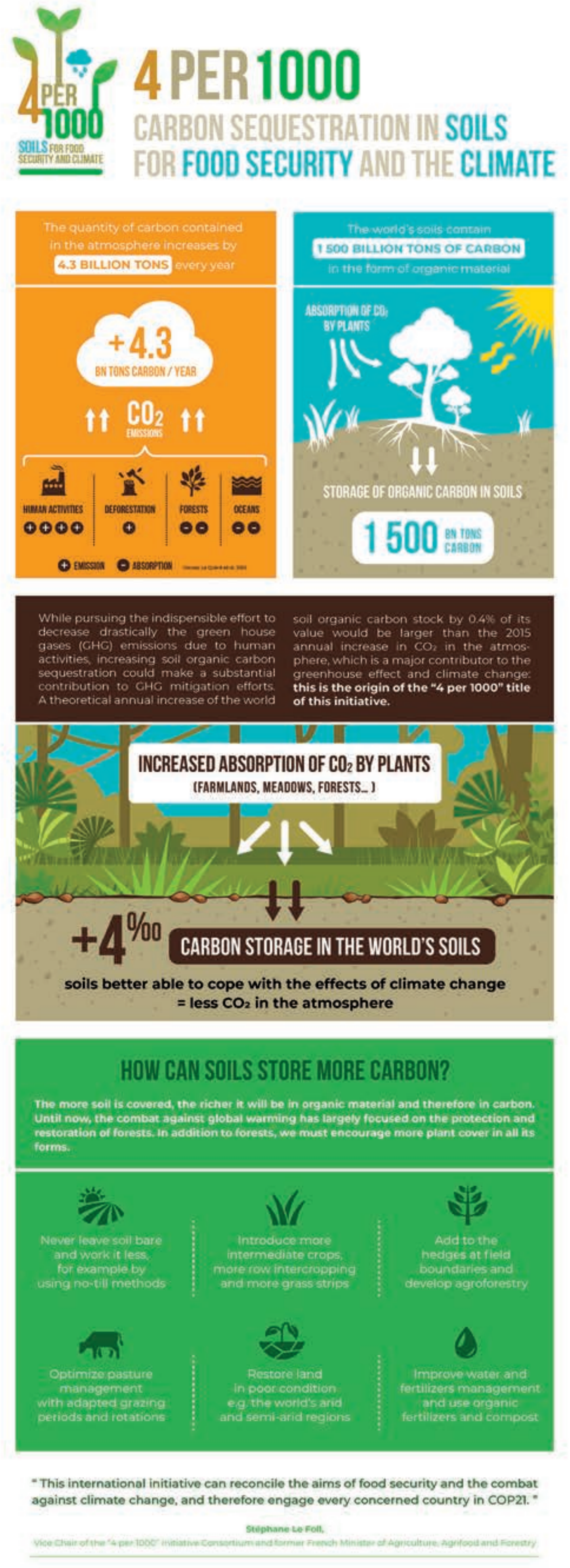


fig. 36: 4 per 1000 Initiative at a glance

A.3.3 Proeftuin ontharden (BE)

Summary of initiative: The project Proeftuinen ontharding combines 45 projects, that resulted from 2 open calls (09/2018 & 04/2019) coming from the Flemish Department of Environment. It's goal is to stimulate a reduction of hardened surface in Belgium by analysing and summarizing in a book what the quick wins, the difficulties and the important aspects were in all these projects. After the successful first open call, a second open call focused on 3 thematical purposes: schools and surroundings (focus on better schoolsurroundings and coalitions with their neighbourhoods), more space for water (making built neighbourhoods more climate-robuste by giving water more space) and 'away ways' (where the focus is on the softening of infrastructure).

Actors involved: Departement Omgeving Vlaanderen in collaboration with Architecture Workroom Brussels for the redaction of a summarizing book "Proeftuinen Ontharding Werkboek". In the 45 projects multiple designers worked on different projects: PT architecten, MAARCH + Groenlab, Fris in het Landschap, 51N4E + Plant en houtgoed and Stramien

Condition that they tackled: The soil and open space contains vital functions to maintain an ecological balance. In Flanders, every day around 6 ha's are hardened resulting in a 16% of the total surface that is hardened. Too much of hardened surface such as driveways, parking lots, housing and industry makes it harder for water to infiltrate in the soil, and thus let this soil fulfil its ecological regenerative purpose and make Flanders more climate-robust.

Definition of tool: Next regional grants (10 million euro for 44 projects), a workbook was developed that aims to provide inspiration for all living labs that are already working today, new coalitions in the field and (supra) local governments that want to start softening.

Impact in number: 12 ha softened. [54]

Impact: The impact of this project is not yet really visible as a lot of the living labs still need to be executed. However, one can say that it's not really about the amount of m² that are being renaturalised in those 44 projects but more on which lessons should be learned so that Flanders can reduce it's percentage of hardening systematically on a bigger scale. In this regard, they learn from the trial projects what the quick-wins are, which new coalitions are interesting and how systemic projects can influence the governance.

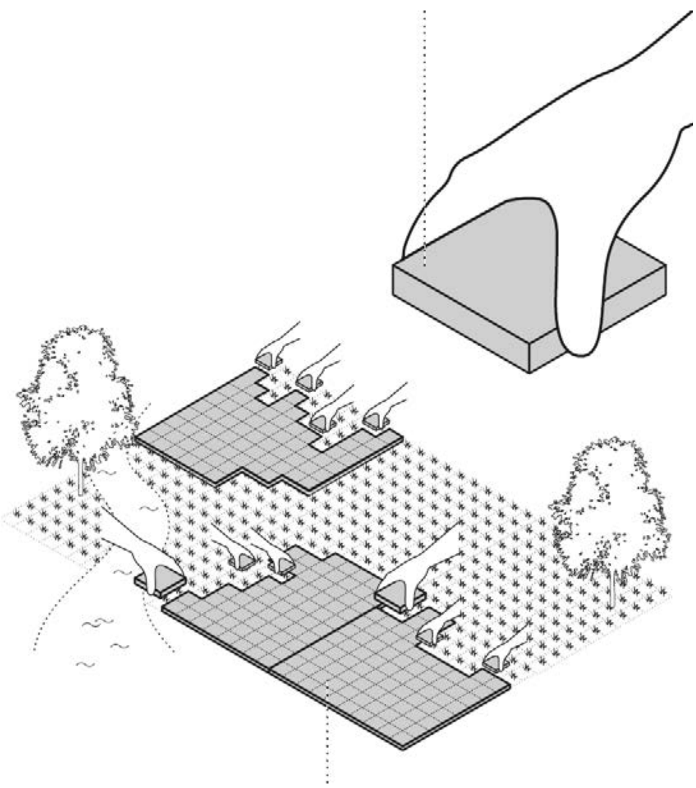


fig. 37: depaving scheme from Werkboek Proeftuinen Ontharding.

A.4 Proximity
A.4.1 ACT: Fairpark (CH)
A.4.2 ACT: Cargo vélo (BE)
A.4.3 ACC: Imslux (LUX)

A.4.1 ACT: Fairpark (CH)

Summary of initiative: Fairpark is an online solution for parking and mobility management. It manages parking spaces at workspace, organises carpooling within companies and promotes different modes of transport by incorporating other mobility services offered by the company (such as subsidies for public transport, bonuses for the use of active modes of transport, etc.)

Actors involved: Mobilidee and municipalities

Condition that they tackled: parking problems, traffic jams and oversized car infrastructure

Impact: The app is used by 90 000 peoples and multiple (international) firms. Better use of available parking space, making more space for other use. They manage over 30 000 parking spaces and claim to have freed up over 2 million parking spaces. At 12,5 m^2 per parking space, that would result in over 25 million m^2 or 2 500 ha that could be greened. [55]

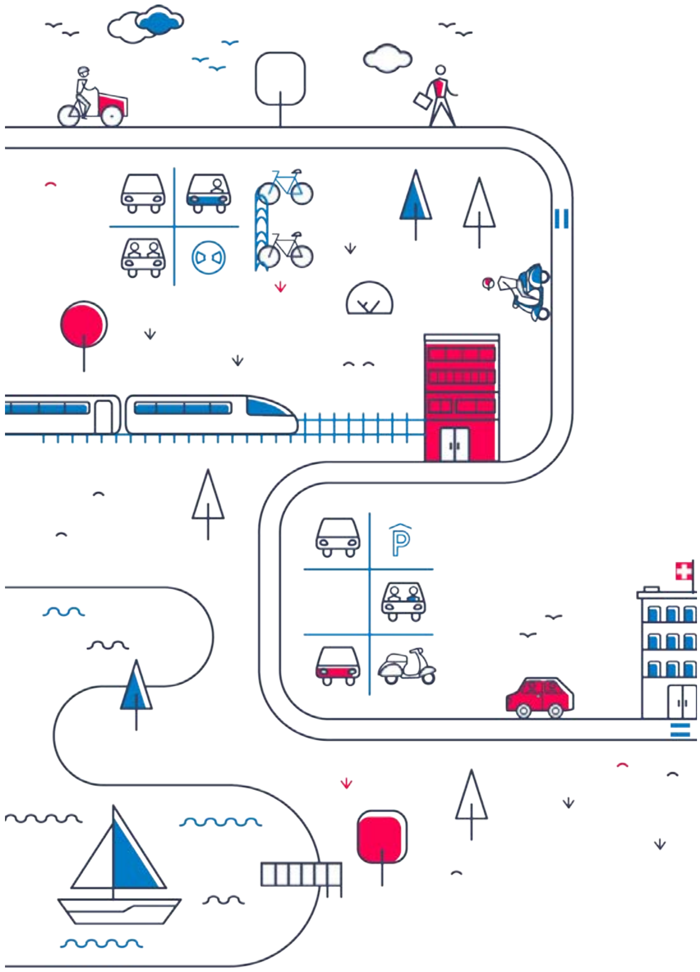


fig. 38: Fairpark illustration

A.4.2 ACT: Cargo vélo (BE)

Summary of initiative: bikedelivery system in urban context (Ghent: 6 drivers, Antwerp: 2 drivers and Brussels) . They provide a flexible alternative for motorised transport, carrying goods from flowers, to medicins, printed matters, ... They work for hospitals, schools, supermarkets, etc.. Deliveries can go up to 120 kg, and 1.2m^3. They deliver on command, but also have connection between the three big cities, where their bike-services are connected to electrical intercity shuttles.

Impact: with an average of 100 000 km/ year an estimated 15800 kg CO2 [56]

image 21: Cargo Velo in the city.

A.4.3 ACC: Imslux (LUX)

Summary of initiative: Imslux is a leading network of companies in Luxembourg who're actively working for more than 10 years on their corporate social responsibility. The independent and apolitical organisation explores new solutions with a positive environmental impact and tests them via groupworks and pilot projects. IMS facilitates innovative initiatives by mobilising all stakeholders in various manners. They're the national representative at the European organisation CSR, leader in Corporate Social responsibility.

Actors involved: 151 members (representing 16% workforces of Luxembourg)

Condition that they tackled: unsustainable transport

Definition of tool: raising awareness & inform, animate the leading CSR Network, provide their expertise and propose concrete solutions

Impact: The impact of IMS is bringing together stakeholders and let them network. 64 events organised, with 1700 participants and 15 publications. [57]

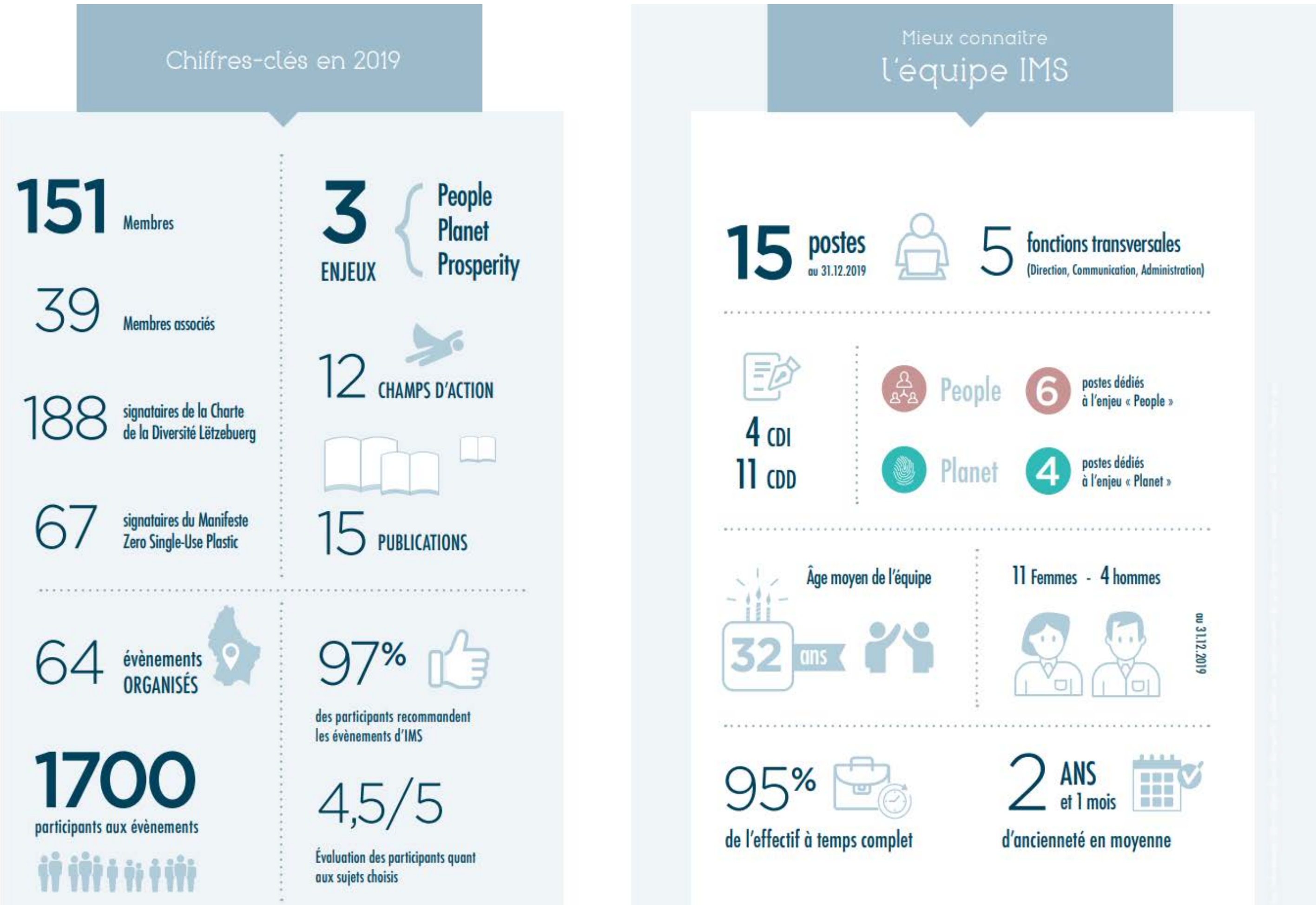


fig. 39: IMS Luxembourg activities.

5.2 Initiatives

A.5 Diet

A.5.1 ACT: Days without Meat (BE)

A.5.2 ACT: Too Good To Go (INT)

A.5.3 ACC: True Price + De Aanzet (NL)

A.5.1 ACT: Days without Meat (BE)

Summary of initiative: Days Without Meat was a ecological citizens initiative where participants abstained from meat consumption for about 40 days during Lent. It started as a Facebook group in 2011 but grew to a big "event" with over 70 000 participants in 2016, including the presidents of the five biggest political parties in Belgium. Every year, it was a period where multiple celebrities, companies and shops held actions around vegetarian food and ways to make it more "sexy". The initiative isn't active anymore as it was in 2011-2017. Their facebookpage with around 30 000 followers now focusses on sharing news, inspirations and recipies for more sunstainability.

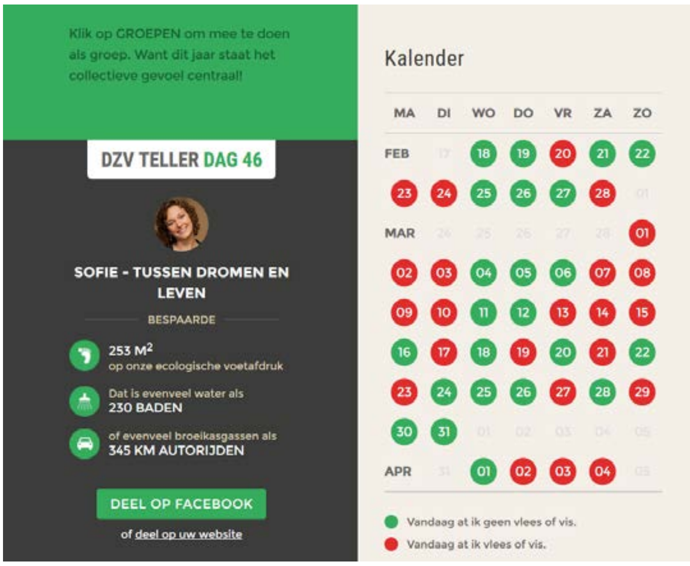


fig. 40: Days without Meat online blog.

Actors involved: mainly citizens, but also quite some public figures

Condition that they tackled: the environmental impact of meat-consumption, and the big ecological footprint that the average Belgian has (the 5th biggest in the world)

Definition of tool: the tool was a website, and an app where participants could see how much water, and CO2emissions they saved by not eating meat. Also a Days Without Meat-cookbook was released by famous chefs. In second fase they used challenges (between cities, youthgroups, schools, ...) as a way to multiply their impact and raise competitiveness.

Impact: started in 2011 with 11 000 registrated participants, to 55 000 participants in 2015 and 72 000 participants in 2016 (with an estimated lowered ecological footprint of 8,8 million m² or 1,6 million kg of CO2). [58]

A.5.2 ACT: Too Good To Go (INT)

Summary of initiative: Too Good to Go connects local restaurant holders with civilians to save food that otherwise would be thrown away. Users of the app are able to order left-overs from restaurants, with big discounts, resulting in a win-win: no food that gets thrown away, support for local economy and cheap meals for civilians. [59]

Actors involved: households, businesses, schools & public affairs

Condition that they tackled: food spillage.

Definition of tool: An online order-app where participating restaurants/shops can sell their left-overs to users.

Impact: Worldwide, Too Good to Go has more than 29 million users and saved more than 54 million meals. The organization calculated that for every meal that is not thrown away, 2.5 kg of CO2 is saved. This results in a total saving of 136,000,000 kg C02. [60]

image 22: Too Good to Go from the website.

A.5.3 ACC: True Price + De Aanzet (NL)

Summary: the first supermarket in the world who internalises the real environmental costs to its product prices. They take climate-tax, land use, under payment in to count, to become the real price of the goods. However, it's not yet possible to really bring the extra money clients pay to the exact place where it damaged the ecosystem. Therefore they donate the extra raised money, that's calculated by average by True Price, to different organisations who are structurally countering similar problems.[61]

Actors involved: True Price, Land Live Company (reforestation company), Give Directly (NGO helping extremely poor African families)

Condition they tackled: compensate the externalised (environmental) costs connected to goods

Definition of the tool: True Price Database with 31 indicators that calculates the real price of goods

Impact: True Price makes the difference by emitting very little, and much more by helping others to emit less. Quantitative calculations are therefore difficult.[62]

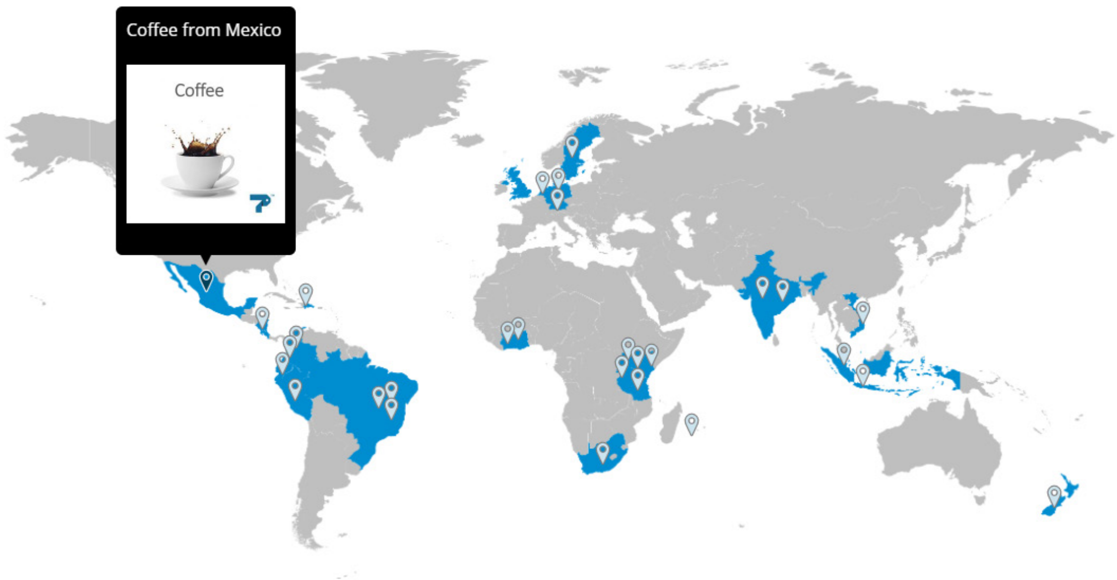


fig. 41: True price world map from the website.

FIGURES

5.3 Figures

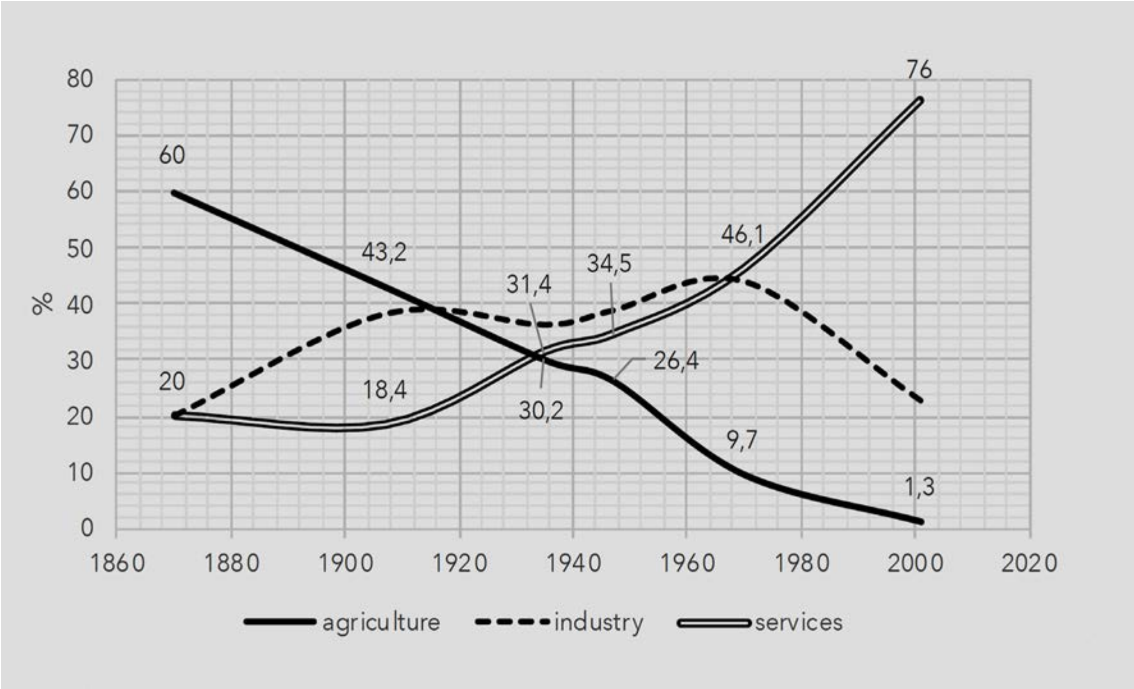


fig. a: The striking evolution of Luxembourg's active population, from 1870 to 2001.
.data sources:
Trausch, G., Gengler, C. Margue, M., Metzler, J.(2003). Histoire du Luxembourg: Le destin européen d'un "petit pays." Privat, Toulouse.

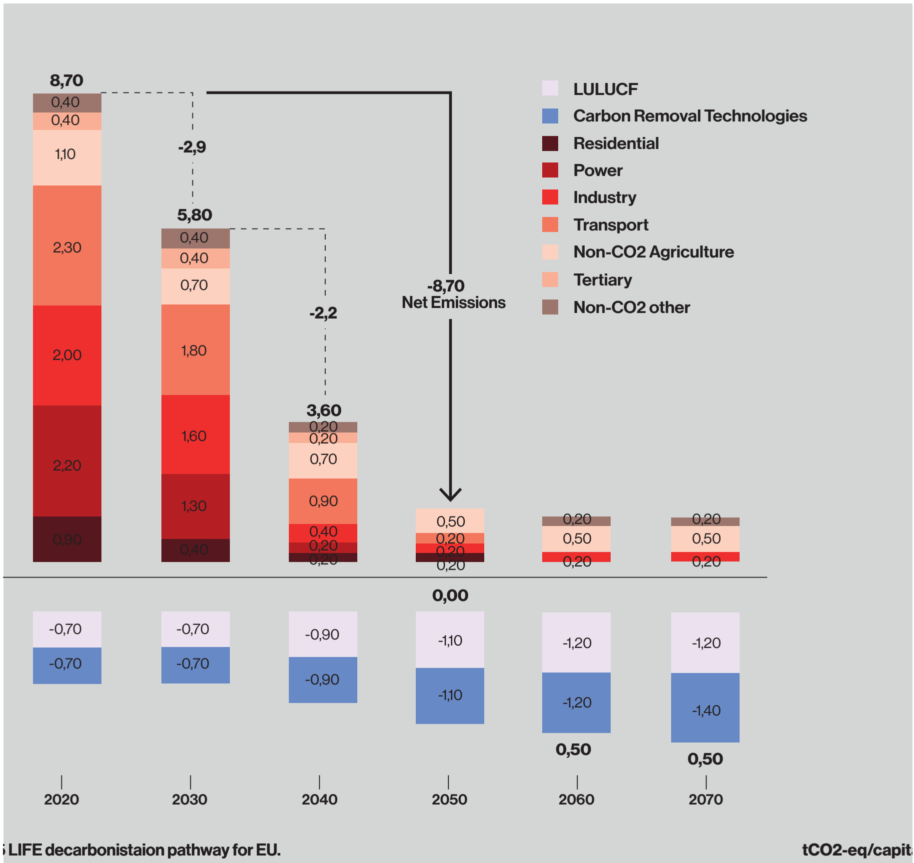


fig. b: EU 1.5 LIFE Scenario tCO2eq/capita/year.
.data sources:
fig. 3 net zero GHG emission pathways for 1.5 LIFE scenario

5.3 Figures

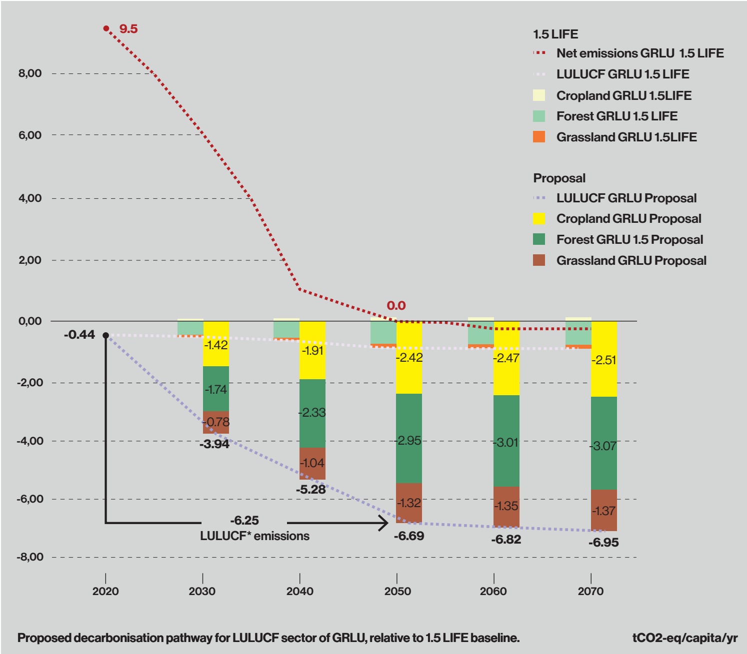


fig. c: GRLU proposal - tCO2eq/capita/yr
.data sources:
fig. 3 net zero GHG emission pathways for 1.5 LIFE scenario
fig. g sequestration tools
fig. b 1.5 LIFE projections for EU
reference 65 has been used for population projections

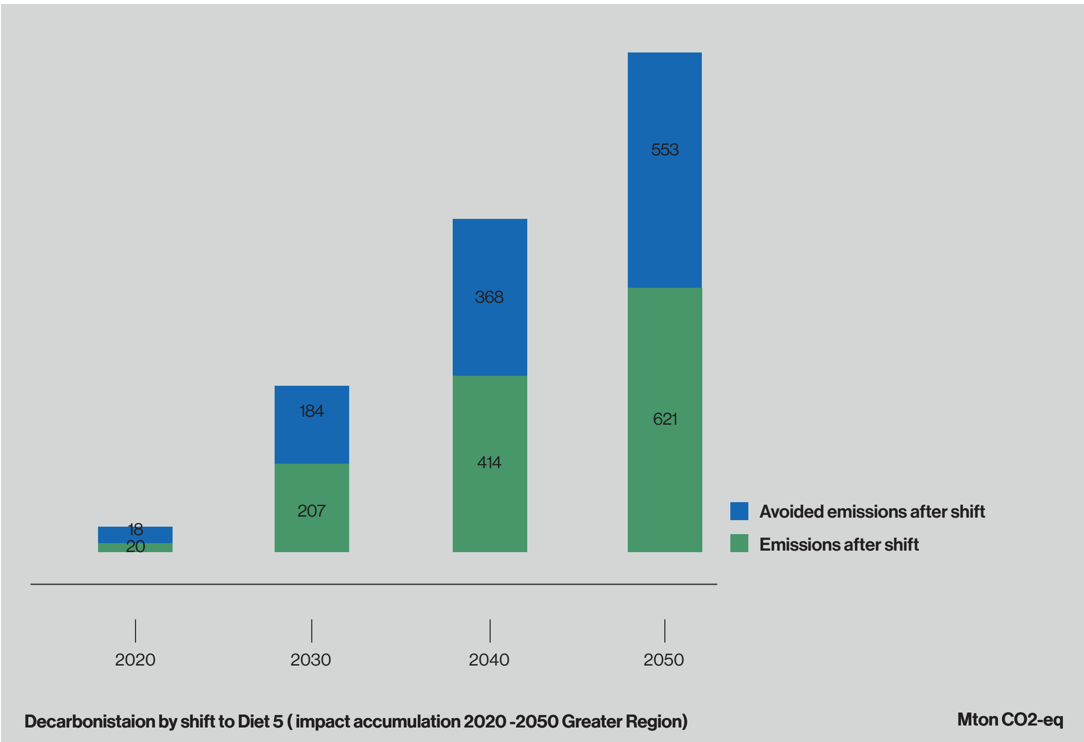


fig. d: diet shift (impact accumulation 2020-2050 GRLU) Mton CO2-eq
.data sources:
fig. 4 diet 5
fig. 5 current meat consumption Luxembourg (2017)
fig. 6 kgC02 eq / kg food
fig. 7 kgC02 eq / kcal food
fig. 8 kgC02 eq / 100 grams of protein
reference 65 has been used for population projections

5.3 Figures

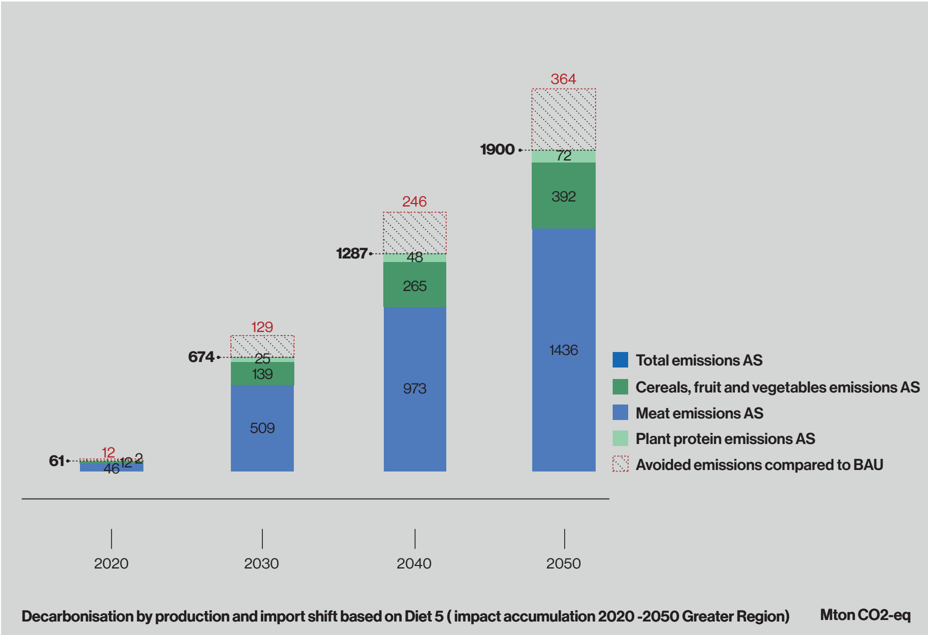


fig. e: Production and import shift (impact accumulation 2020-2050 GRLU) Mton CO2-eq.
.data sources:
fig. 9 **cereal production Luxembourg (2019)**
fig. 10 **fruit (primary) and vegetable production Luxembourg (2018)**
fig. 11 **fruit and vegetable import Luxembourg (2018)**
fig. 12 **cereal import Luxembourg (2018)**
fig. 13 **meat production Luxembourg (2018)**
fig. 14 **meat import Luxembourg (2018)**
fig. 6 **kgC02 eq / kg food**
fig. 15 **kcal / kg food**

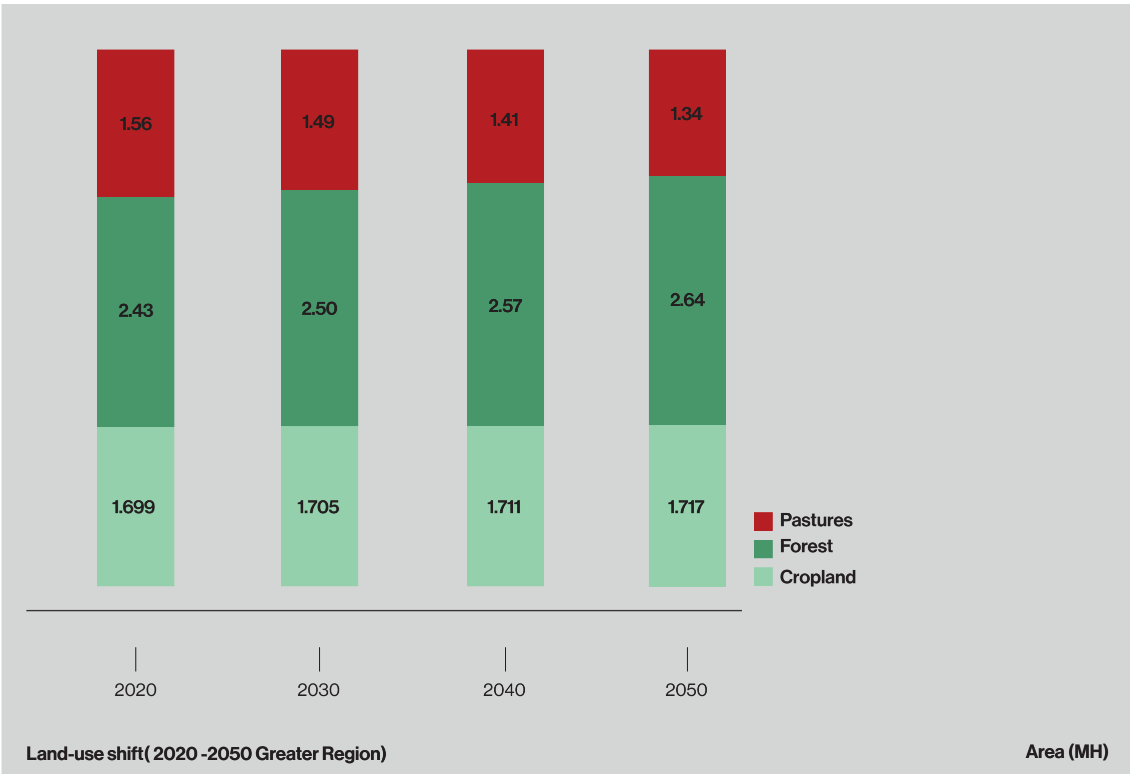


fig. f: Landuse shift (impact accumulation 2020-2050 GRLU) Area (MH)
.data sources:
fig. 16 **landcover (2018)**

5.3 Figures

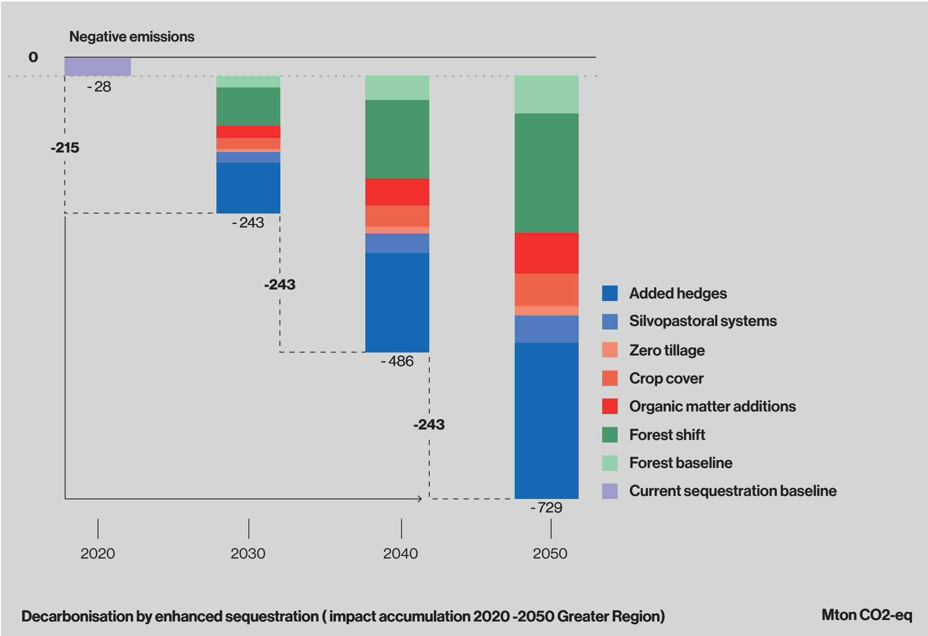


fig. g: sequestration (impact accumulation 2020-2050 GRLU) Mton CO2-eq.
.data sources:
fig. 17: **current baseline for Luxembourg**
fig. 18: organic matter additions
fig. 19: zero tillage
fig. 20: cover crops
fig. 21: hedges
fig. 22: silvopastoral systems
reference 65 has been used for population projections

fig. i: Construction shift - Mton CO2-eq
.data sources:
fig. 23 demand for extra housing Luxembourg
fig. 24 projected wood harvest amounts
fig. 25 effect on emission comparison conventional housing unites and CLT housi
reference 65 has been used for population projections

5.3 Figures

	Electrification (ELEC)	Hydrogen (H2)	Power-to-X (P2X)	Energy Efficiency (EE)	Circular Economy (CIRC)	Combination (COMBO)	1.5°C Technical (1.5TECH)	1.5°C Sustainable Lifestyles (1.5LIFE)
Main Drivers	Electrification in all sectors	Hydrogen in industry, transport and buildings	E-fuels in industry, transport and buildings	Pursuing deep energy efficiency in all sectors	Increased resource and material efficiency	Cost-efficient combination of options from 2°C scenarios	Based on COMBO with more BECCS, CCS	Based on COMBO and CIRC with lifestyle changes
GHG target in 2050	-80% GHG (excluding sinks) ["well below 2°C" ambition]					-90% GHG (incl. sinks)	-100% GHG (incl. sinks) ["1.5°C" ambition]	
Major Common Assumptions	• Higher energy efficiency post 2030 • Deployment of sustainable, advanced biofuels • Moderate circular economy measures • Digitilisation • Market coordination for infrastructure deployment • BECCS present only post-2050 in 2°C scenarios • Significant learning by doing for low carbon technologies • Significant improvements in the efficiency of the transport system.							
Power sector	Power is nearly decarbonised by 2050. Strong penetration of RES facilitated by system optimization (demand-side response, storage, interconnections, role of prosumers). Nuclear still plays a role in the power sector and CCS deployment faces limitations.							
Industry	Electrification of processes	Use of H2 in targeted applications	Use of e-gas in targeted applications	Reducing energy demand via Energy Efficiency	Higher recycling rates, material substitution, circular measures	Combination of most Cost-efficient options from "well below 2°C" scenarios with targeted application (excluding CIRC)	COMBO but stronger	CIRC+COMBO but stronger
Buildings	Increased deployment of heat pumps	Deployment of H2 for heating	Deployment of e-gas for heating	Increased renovation rates and depth	Sustainable buildings			CIRC+COMBO but stronger
Transport sector	Faster electrification for all transport modes	H2 deployment for HDVs and some for LDVs	E-fuels deployment for all modes	Increased modal shift	Mobility as a service			• CIRC+COMBO but stronger • Alternatives to air travel
Other Drivers		H2 in gas distribution grid	E-gas in gas distribution grid				Limited enhancement natural sink	• Dietary changes • Enhancement natural sink

fig 1: **European Commission. (2018).** In-depth analysis in support on the COM(2018) 773: A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy. https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

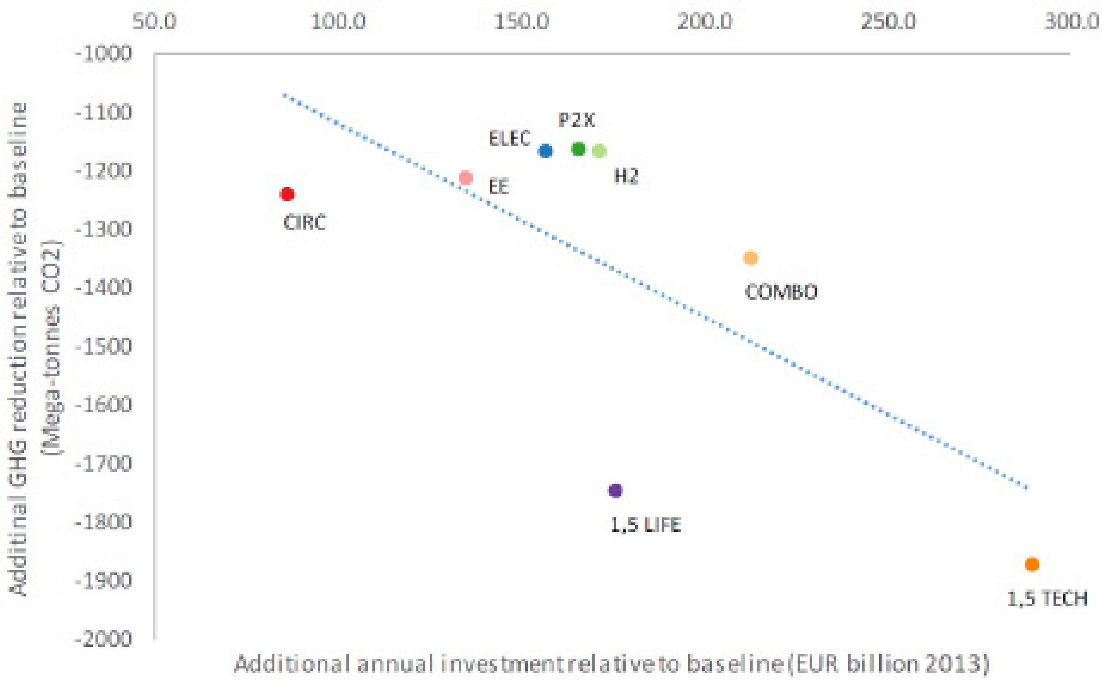
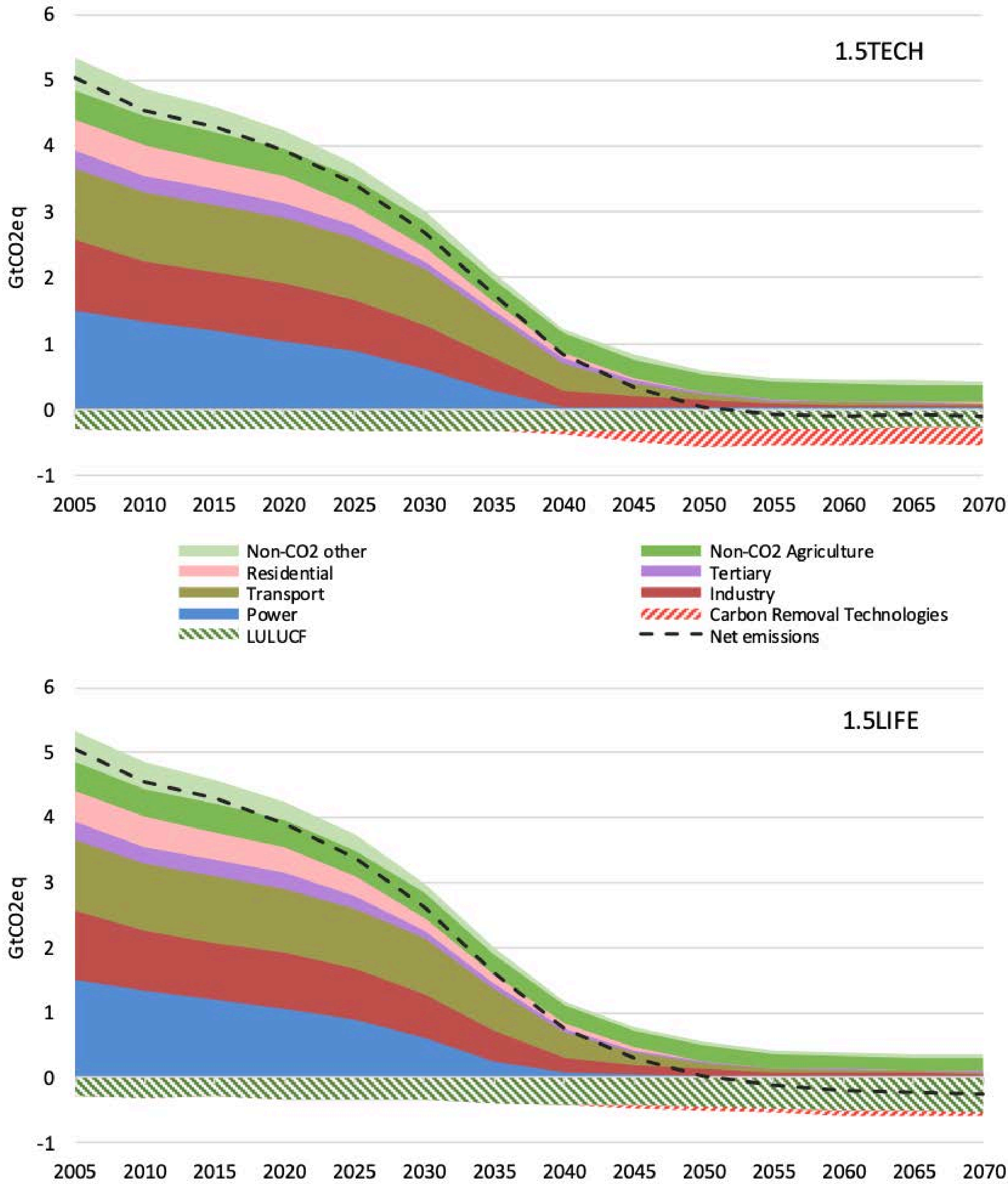


fig. 2: **European Commission. (2018). IN-DEPTH ANALYSIS IN SUPPORT OF THE COMMISSION COMMUNICATION COM(2018) 773 A Clean Planet for all - A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy.** **https://ec.europa.eu/clima/sites/clima/files/strategies/2050/docs/long-term_analysis_in_depth_analysis_figures_20190722_en.pdf**

5.3 Figures

Figure 90: Two ways to reach net zero GHG emissions - reduction pathways for 1.5TECH (above) and 1.5LIFE scenario (below) with enhanced LULUCF sink[451]



Source: PRIMES, GAINS, GLOBIOM.

fig. 3: **European Commission. (2018).** In-depth analysis in support on the COM(2018) 773: A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy. https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

5.3 Figures

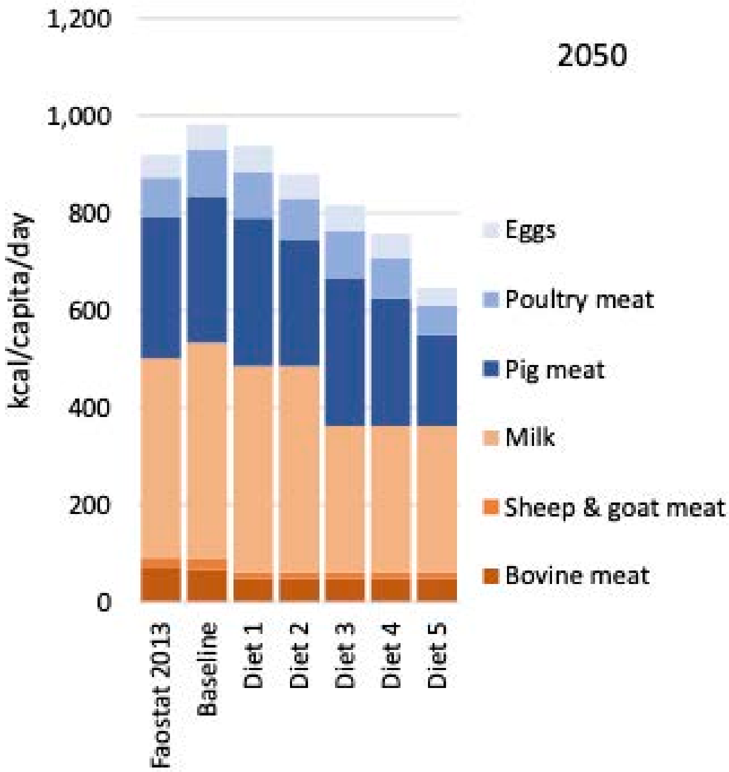


fig 4: **European Commission. (2018). IN-DEPTH ANALYSIS IN SUPPORT OF THE COMMISSION COMMUNICATION COM(2018) 773 A Clean Planet for all - A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy. https://ec.europa.eu/clima/sites/clima/files/strategies/2050/docs/long-term_analysis_in_depth_analysis_figures_20190722_en.pdf**

Area	Element Code	Element	Item Code	Item	Year Code	Year	Unit	Value
Luxembourg	664	Food supply (kcal/capita/day)	2943	Meat	2017	2017	kcal/capita/day	531
Luxembourg	664	Food supply (kcal/capita/day)	2731	Bovine Meat	2017	2017	kcal/capita/day	143
Luxembourg	664	Food supply (kcal/capita/day)	2732	Mutton & Goat Meat	2017	2017	kcal/capita/day	9
Luxembourg	664	Food supply (kcal/capita/day)	2733	Pigmeat	2017	2017	kcal/capita/day	304
Luxembourg	664	Food supply (kcal/capita/day)	2734	Poultry Meat	2017	2017	kcal/capita/day	69
Luxembourg	664	Food supply (kcal/capita/day)	2735	Meat, Other	2017	2017	kcal/capita/day	6
Luxembourg	664	Food supply (kcal/capita/day)	2948	Milk - Excluding Butter	2017	2017	kcal/capita/day	344

fig. 5: **New Food Balances. (2017). Http://Www.Fao.Org/Faostat/En/#data/FBS. http://www.fao.org/faostat/en/#data/FBS**

5.3 Figures

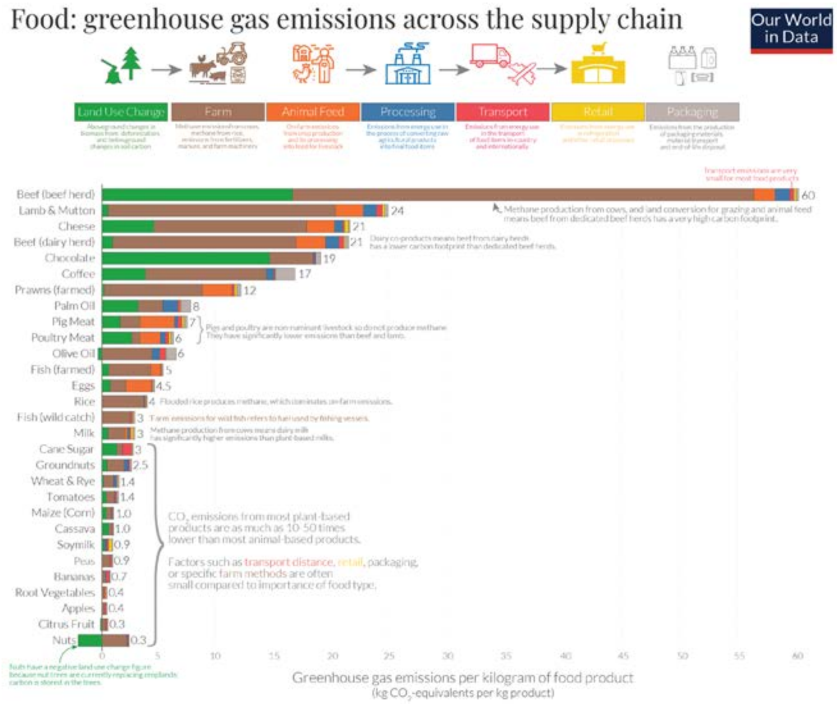


fig. 6: **Ritchie, H. (2020) You want to reduce the carbon footprint of your food? Focus on what you eat, not whether your food is local. Our World in Data. https://ourworldindata.org/food-choice-vs-eating-local**

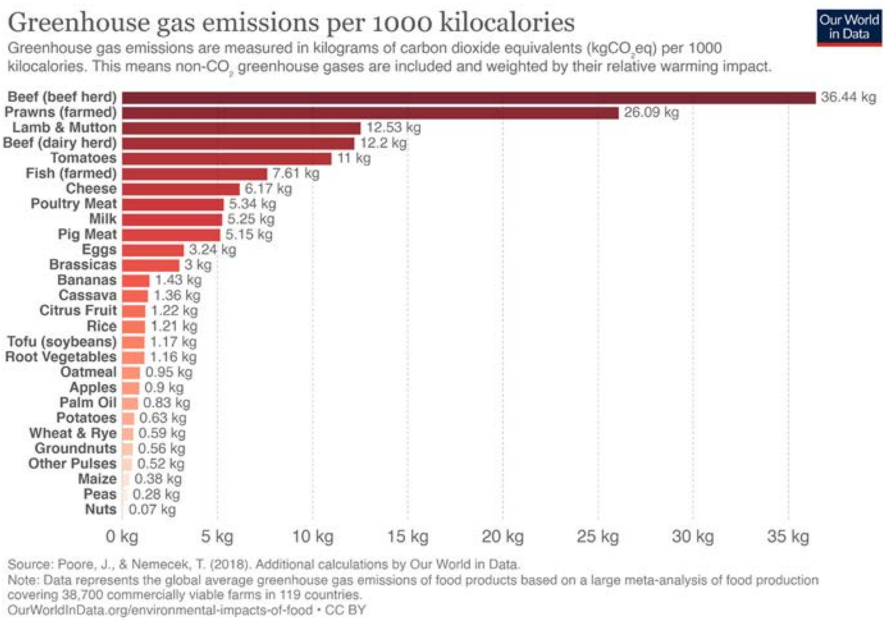


fig. 7: **Ritchie, H. (2020). Environmental impacts of food production. Our World in Data. https://ourworldindata.org/environmental-impacts-of-food#the-carbon-footprint-of-eu-diets-where-do-emissions-come-from**

5.3 Figures

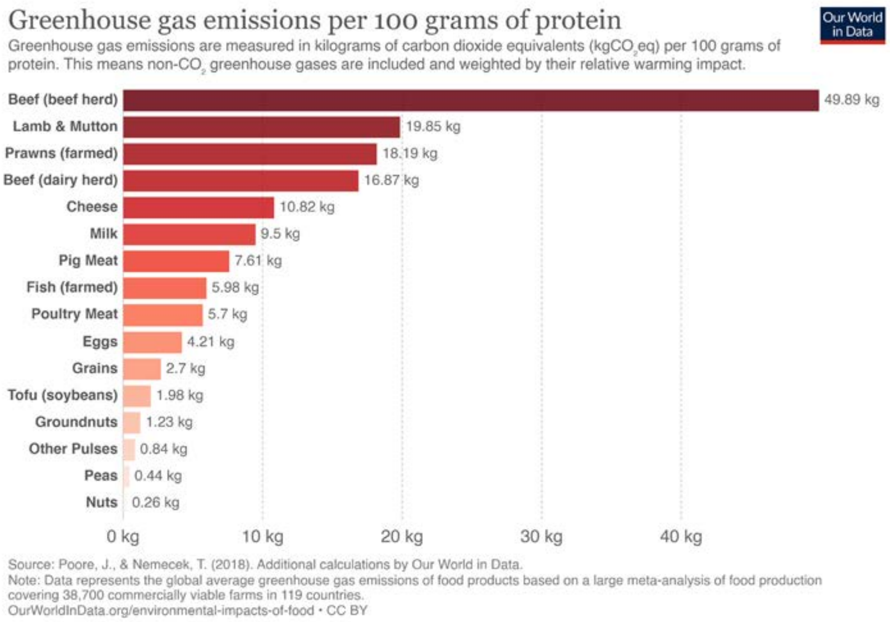


fig. 8: **Ritchie, H. (2020). Environmental impacts of food production. Our World in Data. https://ourworldindata.org/environmental-impacts-of-food#the-carbon-footprint-of-eu-diets-where-do-emissions-come-from**

Quantities produced of main crop and fodder productions (in tonnes) 1960 - 2019

Other:

Year / Specification	1960	1970	1980	1990	2000	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total cereals	119 172	108 767	120 670	147 439	152 830	166 185	149 591	153 429	173 300	168 564	176 516	139 272	149 289	154 236	160 022

fig. 9: **Quantités produites des principales productions de grande culture et fourragères (en tonnes) 1960 - 2019 Documentation du tableau. (2019). Https://Statistiques.Public.Lu. https://statistiques.public.lu/stat/Common/ErrorMsg/ErrorPage.aspx?aspxerrorpath=/stat/ReportFolders/ReportFolder.aspx**

Area	Element Code	Element	Item Code	Item	Year Code	Year	Unit	Value	Flag
Luxembourg	5510	Production	1738	Fruit Primary	2018	2018	tonnes	20639	A
Luxembourg	5510	Production	1735	Vegetables Primary	2018	2018	tonnes	1914	A

fig. 10: **Food and Agriculture Organization of the United Nations. (2018). Production: crops. Http://Www.Fao.Org. http://www.fao.org/faostat/en/#data/QC**

5.3 Figures

Item	Year	Unit	Value
Almonds shelled	2018	tonnes	315
Almonds, with shell	2018	tonnes	16
Apples	2018	tonnes	5603
Apricots	2018	tonnes	606
Apricots, dry	2018	tonnes	27
Artichokes	2018	tonnes	371
Asparagus	2018	tonnes	446
Avocados	2018	tonnes	1933
Bambara beans	2018	tonnes	0
Bananas	2018	tonnes	6053
Beans, dry	2018	tonnes	158
Beans, green	2018	tonnes	431
Blueberries	2018	tonnes	238
Brazil nuts, shelled	2018	tonnes	13
Broad beans, horse bea	2018	tonnes	8
Cabbages and other br	2018	tonnes	1628
Carrots and turnips	2018	tonnes	4192
Cashew nuts, shelled	2018	tonnes	2759
Cashew nuts, with shel	2018	tonnes	5
Cassava dried	2018	tonnes	21
Cauliflowers and brocc	2018	tonnes	1357
Cherries	2018	tonnes	425
Cherries, sour	2018	tonnes	2
Chestnut	2018	tonnes	168
Chick peas	2018	tonnes	64
Chillies and peppers, gı	2018	tonnes	1886
Coconuts	2018	tonnes	80
Coconuts, desiccated	2018	tonnes	16
Cranberries	2018	tonnes	0
Cucumbers and gherkiı	2018	tonnes	2495
Currants	2018	tonnes	29
Dates	2018	tonnes	91
Eggplants (aubergines)	2018	tonnes	568
Figs	2018	tonnes	132
Figs dried	2018	tonnes	55
Flour, potatoes	2018	tonnes	77
Flour, pulses	2018	tonnes	17
Flour, roots and tubers	2018	tonnes	25
Fruit, cooked, homoge	2018	tonnes	201
Fruit, dried nes	2018	tonnes	335
Fruit, fresh nes	2018	tonnes	896
Fruit, prepared nes	2018	tonnes	4770
Fruit, tropical fresh nes	2018	tonnes	24
Garlic	2018	tonnes	368
Grapefruit (inc. pomelo	2018	tonnes	334
Grapes	2018	tonnes	2498
Groundnuts, prepared	2018	tonnes	2809
Hazelnuts, shelled	2018	tonnes	61
Hazelnuts, with shell	2018	tonnes	17
Juice, apple, concentra	2018	tonnes	232
Juice, apple, single stre	2018	tonnes	1587
Juice, citrus, concentra	2018	tonnes	20
Juice, citrus, single stre	2018	tonnes	115
Juice, fruit nes	2018	tonnes	3439
Juice, grape	2018	tonnes	293
Juice, grapefruit	2018	tonnes	28
Juice, grapefruit, conce	2018	tonnes	75
Juice, lemon, concentra	2018	tonnes	1
Juice, lemon, single str	2018	tonnes	78
Juice, orange, concentr	2018	tonnes	2624
Juice, orange, single st	2018	tonnes	2525
Juice, pineapple	2018	tonnes	248
Juice, pineapple, conce	2018	tonnes	161
Juice, tomato	2018	tonnes	237
Kiwi fruit	2018	tonnes	1270
Kola nuts	2018	tonnes	1
Leeks, other alliaceous	2018	tonnes	819
Lemons and limes	2018	tonnes	1707
Lentils	2018	tonnes	127
Lettuce and chicory	2018	tonnes	2866
Mangoes, mangosteen	2018	tonnes	1471
Melons, other (inc.cant	2018	tonnes	2777
Mushrooms and truffle	2018	tonnes	1493
Mushrooms, canned	2018	tonnes	513
Nuts nes	2018	tonnes	531
Nuts, prepared (exc. gr	2018	tonnes	936
Olives	2018	tonnes	170
Olives preserved	2018	tonnes	1823
Onions, dry	2018	tonnes	3051
Onions, shallots, green	2018	tonnes	349
Oranges	2018	tonnes	6043
Papayas	2018	tonnes	657
Peaches and nectarine	2018	tonnes	1935
Pears	2018	tonnes	1920
Peas, dry	2018	tonnes	399
Peas, green	2018	tonnes	67
Persimmons	2018	tonnes	130
Pineapples	2018	tonnes	2381
Pineapples canned	2018	tonnes	217
Pistachios	2018	tonnes	8735
Plantains and others	2018	tonnes	808
Plums and sloes	2018	tonnes	699
Plums dried (prunes)	2018	tonnes	46
Potatoes	2018	tonnes	10653
Potatoes, frozen	2018	tonnes	6438
Pumpkins, squash and	2018	tonnes	1919
Quinces	2018	tonnes	9
Raisins	2018	tonnes	533
Roots and tubers nes	2018	tonnes	18
Soybeans	2018	tonnes	65
Spinach	2018	tonnes	170
Strawberries	2018	tonnes	1932
Sugar beet	2018	tonnes	5
Sweet corn frozen	2018	tonnes	78
Sweet corn prep or pre	2018	tonnes	334
Sweet potatoes	2018	tonnes	276
Tangerines, mandarins	2018	tonnes	2988
Tomatoes	2018	tonnes	5754
Tomatoes, paste	2018	tonnes	1578
Tomatoes, peeled	2018	tonnes	3461
Vegetables in vinegar	2018	tonnes	1651
Vegetables, dehydrate	2018	tonnes	350
Vegetables, fresh nes	2018	tonnes	5233
Vegetables, fresh or dr	2018	tonnes	58
Vegetables, frozen	2018	tonnes	4243
Vegetables, homogeniz	2018	tonnes	276
Vegetables, preserved	2018	tonnes	6600
Vegetables, preserved,	2018	tonnes	739
Vegetables, temporaril	2018	tonnes	110
Walnuts, shelled	2018	tonnes	77
Walnuts, with shell	2018	tonnes	75
Watermelons	2018	tonnes	1956

fig. 11: **FAOSTAT. (2018). Crops and livestock products import quantity. Http://Www.Fao.Org. http://www.fao.org/faostat/en/#data/TP**

Area	Element Code	Element	Item Code	Item	Year Code	Year	Unit	Value
Luxembourg	5610	Import Quantity	1944	Cereals	2018	2018	tonnes	182084

fig. 12: **FAOSTAT. (2018). Crops and livestock products import quantity. Http://Www.Fao.Org. http://www.fao.org/faostat/en/#data/TP**

Area	Element Code	Element	Item Code	Item	Year Code	Year	Unit	Value
Luxembourg	5510	Production	867	Meat, cattle	2018	2018	tonnes	9955
Luxembourg	5510	Production	1058	Meat, chicken	2018	2018	tonnes	286
Luxembourg	5510	Production	1163	Meat, game	2018	2018	tonnes	400
Luxembourg	5510	Production	1017	Meat, goat	2018	2018	tonnes	4
Luxembourg	5510	Production	1097	Meat, horse	2018	2018	tonnes	4
Luxembourg	5510	Production	1035	Meat, pig	2018	2018	tonnes	12898
Luxembourg	5510	Production	1141	Meat, rabbit	2018	2018	tonnes	28
Luxembourg	5510	Production	977	Meat, sheep	2018	2018	tonnes	45
Luxembourg	5510	Production	1765	Meat, Total	2018	2018	tonnes	23621

fig. 13: **FAOSTAT. (2018). Livestock Primary production quantity. Http://Www.Fao.Org. http://www.fao.org/faostat/en/#data/QL**

5.3 Figures

Area	Element Code	Element	Item Code	Item	Year Code	Year	Unit	Value
Luxembourg	5610	Import Quantity	2077	Total Meat	2018	2018	tonnes	39184

fig. 14: **FAOSTAT. (2019). Crops and livestock products import quantity. Http://Www.Fao.Org. http://www.fao.org/faostat/en/#data/TP**

Beef	100g	248 cal
Beef Brisket	100g	242 cal
Beef Jerky	100g	410 cal
Beef Ribs	100g	238 cal
Beef Tenderloin	100g	218 cal
Chicken	100g	219 cal
Chicken Breast	100g	172 cal
Chicken Drumstick	100g	185 cal
Chicken Fat	100g	898 cal
Chicken Giblets	100g	158 cal
Chicken Gizzards	100g	146 cal
Chicken Leg	100g	174 cal
Chicken Liver	100g	167 cal
Chicken Meat	100g	172 cal
Chicken Thigh	100g	229 cal
Chicken Wing	100g	266 cal
Chuck Steak	100g	277 cal
Cubed Steak	100g	199 cal
Duck	100g	337 cal
Filet Mignon	100g	267 cal
Flank Steak	100g	194 cal
Deep-Fried Tofu	1 oz. (28.35 g)	76 cal
Extra-Firm Tofu	1/5 block (91 g)	83 cal
Firm Tofu	1/4 block (81 g)	57 cal

Flank Steak	100g	194 cal
Flat Iron Steak	100g	137 cal
Ground Beef	100g	246 cal
Ground Round	100g	246 cal
Ham	100g	163 cal
New York Strip Steak	100g	199 cal
Ostrich	100g	145 cal
Pork	100g	196 cal
Pork Baby Back Ribs	100g	212 cal
Pork Chops	100g	196 cal
Pork Country-Style Ribs	100g	247 cal
Pork Loin	100g	204 cal
Pork Roast	100g	254 cal
Pork Steaks	100g	196 cal
Roast Beef	100g	140 cal
Round Steak	100g	182 cal
Schnitzel	100g	156 cal
Spare Ribs	100g	238 cal
Standing Rib Roast	100g	333 cal
T-Bone Steak	100g	202 cal
Turkey	100g	189 cal
Turkey Breast	100g	135 cal
Turkey Legs	100g	208 cal
Turkey Steak	100g	189 cal
Turkey Wings	100g	221 cal

fig. 15: **Calories for Hundreds of Foods: Your Calorie Chart Database. (2019). Calories.Info. https://www.calories.info/**

	(ha)	LUX	WALLONIE	SAARLAND	RHENANIE-PALATINAT	LORRAINE	GREAT REGION
LAND USE	All uses	258600	1690100	257100	1985600	2366900	6558300
	Pasture land	57184,888	392140	69400	447300	599600	1565624,888
	Cropland	72661,531	481260	41900	428200	675300	1699321,531
	Forest land	90550	494760	103100	865800	884800	2439010
	total	220396	1368160	214400	1741300	1560100	5104356,419
	data source	Eurostat landcover 2015					

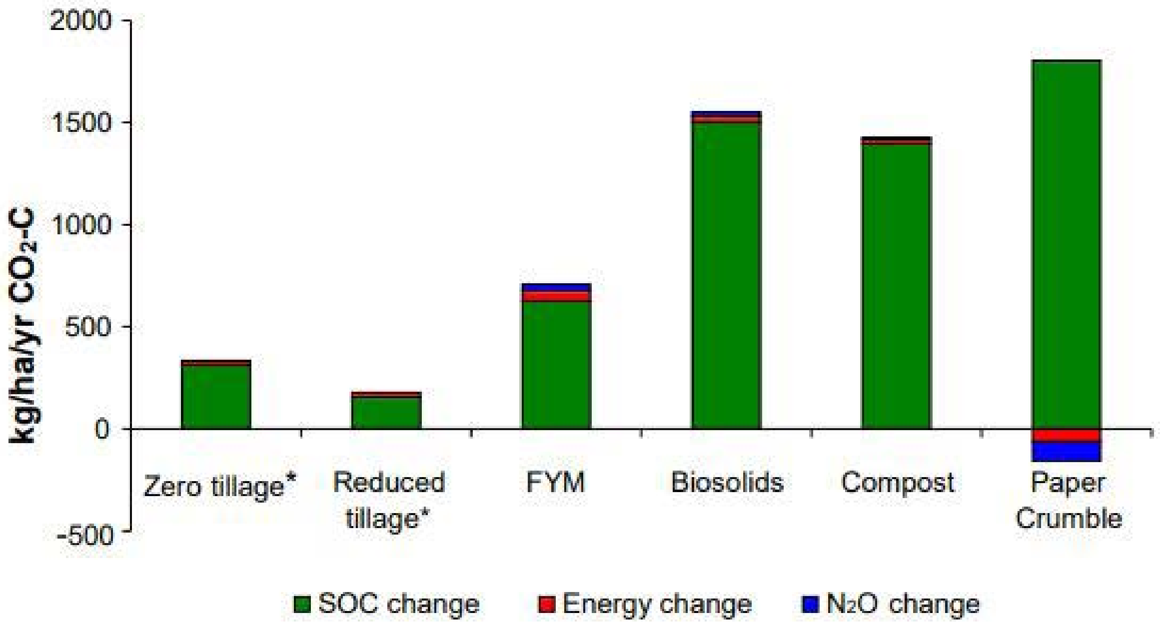
fig. 16: **Eurostat. (2015). Land cover - GISCO - Eurostat. Https://Ec.Europa.Eu. https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/land-cover**

5.3 Figures

Internal code for thi	untr	Country name	Year	Gas/Sc	CRF co	Description as in CRF	Sector_c	Sector_name	Col	Ro	Unit	s with nota	Emissions	Notation k
LU_2019_Total_4	LU	Luxembourg	2019	Total	4	4. Land use, land-use change and forestry(1)	4	4 - Land Use, Land-Use Change and Forestry	J	39	Gg CO2 equivalent	-244,46	-244,46	
LU_2019_Total_4A	LU	Luxembourg	2019	Total	4A	A. Forest land	4.A	4.A - Forest Land	J	40	Gg CO2 equivalent	-282,48	-282,48	
LU_2019_Total_4B	LU	Luxembourg	2019	Total	4B	B. Cropland	4.B	4.B - Cropland	J	41	Gg CO2 equivalent	34,21	34,21	
LU_2019_Total_4C	LU	Luxembourg	2019	Total	4C	C. Grassland	4.C	4.C - Grassland	J	42	Gg CO2 equivalent	-40,63	-40,63	

fig. 17: Approximated estimates for greenhouse gas emissions. (2019). European Environment Agency. https://www.eea.europa.eu/data-and-maps/data/approximated-estimates-for-greenhouse-gas-emissions-2

Figure 1. Maximum CO_2-C 'savings' from zero/reduced tillage and organic material additions to arable land.



Organic material	Application rate (t/ha dry solids-ds)	Potential increase in SOC (kg/ha/yr/t ds)	Potential increase in SOC (kg/ha/yr)
Farm manures	10.5	60	630
Digested biosolids	8.3	180	1500
Green compost	23	60	1400
Paper crumble	30[a]	60[d]	1800[d]
Cereal straw	7.5[b]	50[b]	370

1.3.7 Net carbon storage potential of organic material additions

- The greatest net C 'savings' (taking into account changes in SOC, inorganic fertiliser N manufacture & net N_2O emissions) can be achieved with biosolids, green waste compost and paper crumble additions to land in the range 1400-1600 kg/ha/yr, assuming typical annual application rates (250 kg/ha total N or 75 t/ha fresh weight for paper crumble).

fig. 18: ADAS Gleadthorpe. (2019). The effects of reduced tillage practices and organic material additions on the carbon content of arable soils. https://www.agricology.co.uk/sites/default/files/SP0561_6893_ABS_Final%20report.pdf

5.3 Figures

Site	Clay content (%)	Years	SOC change (kg/ha/yr)[a]	Reference
1. Rothamsted	20	5	-156	Powlson & Jenkinson (1981)
2. Boxworth	43	6	845	
3. Headly Hall I	26	8	292	
4. Penicuik I	13	10	-234	
5. Jealotts Hill	n.d.	2	1365	Tomlinson (1974); Cannell & Finney (1973)
6. Headly Hall II	26	9	607	Chaney (1985)
7. Penicuik II	13	23	509	Ball (1994)
Mean[b] (se)			**310 (176)**	
95% CI			**-140 to 760**	

[a]Difference in SOC between conventional and zero tillage, 0-30cm, assuming a bulk density of 1.3 g cm^{-3}.

fig. 19: ADAS Gleadthorpe. (2019). The effects of reduced tillage practices and organic material additions on the carbon content of arable soils. https://www.agricology.co.uk/sites/default/files/SP0561_6893_ABS_Final%20report.pdf

Results

Annual and cumulative above-ground C assimilation

At both sites, annual and cumulative plant above-ground C contents were calculated and represented the sum of C assimilation from CCs and main crops planted each year and C accrual over the duration of the study, respectively. Differences in C assimilation among years largely reflect the main crop grown and the length of time the cover crop grew as well as weather conditions (Table 1). At both sites, among the tested CCs, OSR (avg. 1.11 Mg C ha^{-1} year^{-1}), had the greatest annual above-ground C content (Table 1). Cumulative CC C inputs were 7.87–8.42 Mg C ha^{-1} at the two sites (Fig. 1). But no differences in the main crop C content among the CC treatments were detected at both sites (Fig. 1). Hence over the 9 years, oilseed radish (OSR, avg. 22.8 Mg C ha^{-1}) had the greatest cumulative plant (main crop and CC) C while no-CC was the least (avg. 13.8 Mg C ha^{-1}, main crop only) at both sites (Fig. 1). Thus, soil C inputs were attributed to CC, rather than main crops.

fig. 20: Chahal, I., Vyn, R. J., Mayers, D., & Van Eerd, L. L. (2020). Cumulative impact of cover crops on soil carbon sequestration and profitability in a temperate humid climate. Scientific Reports, 10(1), 1–11. https://doi.org/10.1038/s41598-020-70224-6

Table 4. Estimations of SOC stocks per hectare under the hedge and uphill of the hedge assuming three hedgerow network densities.

Hedge density (m ha^{-1})			SOC stocks (t C ha^{-1})				Hedge effect (%)
Total	Parallel to contour lines		Under hedge (A)	Uphill 0–30 cm	Uphill >30cm (B)	Total (C)	(A+B)/C
200	100	min	12.0	88.4	15.8	116.1	24
		Mean	**11.7**	**73.0**	**32.1**	**116.8**	**38**
		max	8.8	53.9	44.7	107.4	50
100	50	min	6	88.4	7,9	102.3	13
		Mean	**5.85**	**73**	**16.05**	**94.9**	**23**
		max	4.4	53.9	22.35	80.65	33
50	25	min	3.0	88.4	3.9	95.4	7
		Mean	**2.9**	**73.0**	**8.0**	**83.9**	**13**
		max	2.2	53.9	11.2	67.3	20

fig. 21: Walter, C., Merot, P., Layer, B., & Dutin, G. (2003). The effect of hedgerows on soil organic carbon storage in hillslopes. Soil Use and Management, 19(3), 201–207. https://doi.org/10.1111/j.1475-2743.2003.tb00305.x

Table 3
Agroforestry practices for arable lands and pastures in the European biogeographical regions (an extract of the practices with the lowest, medium, and the highest carbon sequestration potential are shown. See Supplementary material for the complete list and references). (SRC: Short rotation coppice)

Biogeographical region	Agroforestry type	Title	Tree / hedgerow species	Trees [trees ha^{-1}], hedgerow [m ha^{-1}] or wood cover [% ha^{-1}]	Management system	Crop species and products	Tree products	Year of tree harvesting	Carbon sequestration [t C $ha^{-1}a^{-1}$]
Atlantic pasture	Silvopastoral, coppice	Agroforestry for ruminants in France	Pear (*Pyrus* spp), honey locust (*Gleditsia triacanthos*), service tree (*Sorbus domestica*), white mulberry (*Morus alba*), Italian alder (*Alnus cordata*), goat willow (*Salix caprea*), field elm (*Ulmus minor*), black locust (*Robinia pseudoacacia*), grey alder (*Alnus incana*)	(single −2 m, double −6 m, triple −10 m), 4 m for trees, 1.3 m coppices x 20 m, (11% woody cover)	Single, double, or triple lines	Grazing, hay, silage	Fodder-trees, woodchips	5–8	0.16-0.48
Atlantic pasture	Silvopastoral, single trees	Traditional orchard	Fruit trees (apple – *Malus domcestica*, pear - Pyrus spp, plum - *Prunus domestica*)	80 trees ha^{-1}	Lines	Grazing, hay, silage	Fruits (woodchips)	60	1.23
Atlantic pasture	Silvopastoral, single trees	High stem timber trees	Poplar (*Populus* spp)	400 trees ha^{-1}, After 15-20 years: 120-150 trees ha^{-1}	Lines	Grazing, hay, silage	Timber	First cut: 15-20 harvest:25-30	2.78-6.35
Atlantic arable	Silvoarable, hedgerows	Productive boundary hedgerow	Mixed hedgerow species: hawthorn (*Crataegus* spp), blackthorn (*Prunus spinosa*), field maple (*Acer campestre*), hazel (*Corylus avellane*)	0.03% ha^{-1}	Boundary hedgerow	Crop rotation with cereals (wheat, barley, oats), potatoes, squash, organic fertility building ley	Woodchips	Every 15	0.1-0.45
Atlantic arable	Silvoarable, coppice	Alley cropping – Short Rotation Coppice (SRC)	Willow (*Salix viminalis*), hazel (*Corylus avellana*)	1000-1300 trees ha^{-1} (24% ha^{-1})	Twin rows with 10-15 m wide crop alley	Cereals (wheat, barley, oats), potatoes, squash, organic fertility building ley	Woodchips	Every 2 for willow, every 5 for hazel	0.36-1.05
Atlantic arable	Silvoarable, single trees	High stem timber trees	Walnuts (*Juglans regia*), maples (*Acer* spp), wild cherry (*Prunus avium*), checker tree (*Sorbus torminalis*), service tree (*Sorbus domestica*), apple (*Malus domestica*), pear (*Pyrus* spp).	28-110 trees ha^{-1}, (26-50 m between rows)	Lines		Timber	60	Walnut: 0.32-2.75, cherry: 0.19-1.4
Continental hills pasture	Silvopastoral, single trees	Wooded grassland	Fruit trees: cherry (*Prunus avium*), walnut (*Juglans regia*), apple (*Malus domestica*), etc.	60 trees ha^{-1}	Lines	Grazing, hay, silage	Fruits	70-90	Cherry: 0.41-0.76, apple: 0.93-1.43, walnut: 0.86-1.16
Continental lowlands pasture	Silvopastoral, coppice	Agroforestry for free-range pig production	Poplar (*Populus* spp), willow (*Salix* spp), various fruit trees	10-40% ha^{-1} (2.5 × 3.5 m)	SRC lines	Grazing, hay, silage	Woodchips, fodder-trees	5-8	Poplar: 0.44-1.41
Continental hills pasture	Silvopastoral, single trees	High nature and cultural value wood pastures and wooded grasslands	Sessile oak (*Quercus petraea*), beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*), wild fruit trees, mixed poplar (*Populus* spp.), willow (*Salix* spp.)	50-300 trees ha^{-1} (10-50% ha^{-1})	Scattered	Grazing, hay, silage	Acorns, fruits, timber, (fodder-trees)	Trees not harvested	Oak: 0.71-2.83, beech: 0.59-2.34, hornbeam: 0.38-1.55
Continental lowlands arable	Silvoarable, coppice	Alley cropping	Poplar (*Populus* spp); Mixed hedgerow species: willow (*Salix* spp), hornbeam (*Carpinus betulus*), common ash (*Fraxinus excelsior*), common birch (*Betula pendula*), black locust (*Robinia pseudoacacia*)	Rows A, B, and C: 10,000 trees ha^{-1}, Rows D, E, F, and G: 2222 trees ha^{-1}, (10% ha^{-1}).	Single and twin rows with 48, 96, and 144 m wide crop alleys.	Crop rotation (wheat, maize, oilseed rape, barley)	Woodchips	Rows A, B, and C: every 3-5. Rows D, E, F, and G: every 8–10	0.15 - 0.44
Continental hills arable	Silvoarable, single trees	Orchard with vegetables or fruits (strawberries)	Fruit trees: cherry (*Prunus avium*), walnut (*Juglans regia*), apple (*Malus domestica*), etc	60 trees ha^{-1}	Lines	Vegetable, berries (strawberries)	Fruits, timber	70-90	Cherry: 0.41-0.76, apple: 0.93-1.43, walnut: 0.86 -1.16
Continental hills arable	Silvoarable, single trees	Non-native, energy tree with Alfalfa	Pauwlonia (*Paulownia tomentosa*)	126 trees ha^{-1} (18 m x 5 m)	Lines	Triticale, alfalfa	Timber	10-12	3.77

(*continued on next page*)

fig. 22: Kay, S., Rega, C., Moreno, G., den Herder, M., Palma, J. H. N., Borek, R., Crous-Duran, J., Freese, D., Giannitsopoulos, M., Graves, A., Jäger, M., Lamersdorf, N., Memedemin, D., Mosquera-Losada, R., Pantera, A., Paracchini, M. L., Paris, P., Roces-Díaz, J. V., Rolo, V., … Herzog, F. (2019). Agroforestry creates carbon sinks whilst enhancing the environment in agricultural landscapes in Europe. Land Use Policy, 83, 581–593. https://doi.org/10.1016/j.landusepol.2019.02.025

Tableau 9 : Besoins en logements 2018 – 2060

PIB 0%

	2018-2019	2020-2024	2025-2029	2030-2034	2035-2039	2040-2049	2050-2060	Total
Acroissement des ménages	12 748	33 118	31 257	30 833	28 251	45 910	31 109	213226
Renouvellement du parc existant	526	1 445	1 622	1 796	1 964	4 368	5 325	17047
Réserve de mobilité	765	1 987	1 875	1 850	1 695	2 755	1 867	12794
Total	14 040	36 550	34 755	34 479	31 910	53 032	38 301	243066
Par an	**7 020**	**7 310**	**6 951**	**6 896**	**6 382**	**5 303**	**3 482**	**5 653**

PIB 1.5%

	2018-2019	2020-2024	2025-2029	2030-2034	2035-2039	2040-2049	2050-2060	Total
Acroissement des ménages	12 748	33 118	31 257	30 892	29 029	51 331	42 654	231029
Renouvellement du parc existant	526	1 445	1 622	1 796	1 966	4 398	5 455	17209
Réserve de mobilité	765	1 987	1 875	1 854	1 742	3 080	2 559	13862
Total	14 040	36 550	34 755	34 542	32 736	58 809	50 668	262100
Par an	**7 020**	**7 310**	**6 951**	**6 908**	**6 547**	**5 881**	**4 606**	**6 095**

PIB 3%

	2018-2019	2020-2024	2025-2029	2030-2034	2035-2039	2040-2049	2050-2060	Total
Acroissement des ménages	12 748	33 118	31 257	30 953	29 844	57 773	59 624	255317
Renouvellement du parc existant	526	1 445	1 622	1 796	1 967	4 432	5 620	17409
Réserve de mobilité	765	1 987	1 875	1 857	1 791	3 466	3 577	15319
Total	14 040	36 550	34 755	34 606	33 602	65 671	68 821	288046
Par an	**7 020**	**7 310**	**6 951**	**6 921**	**6 720**	**6 567**	**6 256**	**6 699**

PIB 4.5%

	2018-2019	2020-2024	2025-2029	2030-2034	2035-2039	2040-2049	2050-2060	Total
Acroissement des ménages	12 748	33 118	31 257	31 013	30 700	65 426	84 369	288631
Renouvellement du parc existant	526	1 445	1 622	1 796	1 969	4 470	5 830	17659
Réserve de mobilité	765	1 987	1 875	1 861	1 842	3 926	5 062	17318
Total	14 040	36 550	34 755	34 671	34 511	73 822	95 261	323608
Par an	**7 020**	**7 310**	**6 951**	**6 934**	**6 902**	**7 382**	**8 660**	**7 526**

Source : STATEC

fig. 23: STATEC. (2019). Projections des ménages et de la demande potentielle en logements : 2018-2060. https://statistiques.public.lu/catalogue-publications/economie-statistiques/2019/106-2019.pdf

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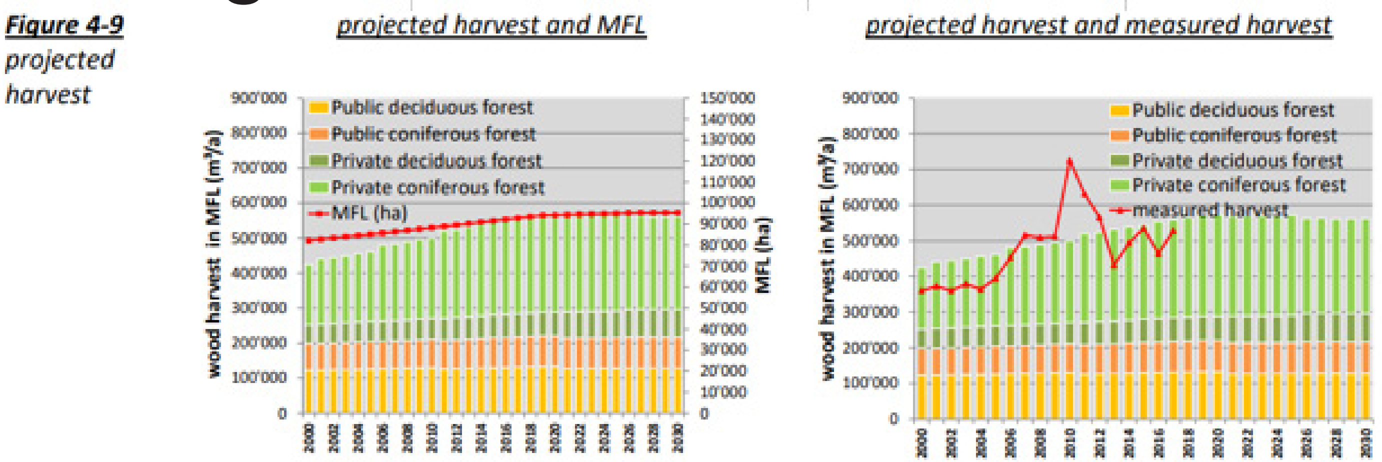
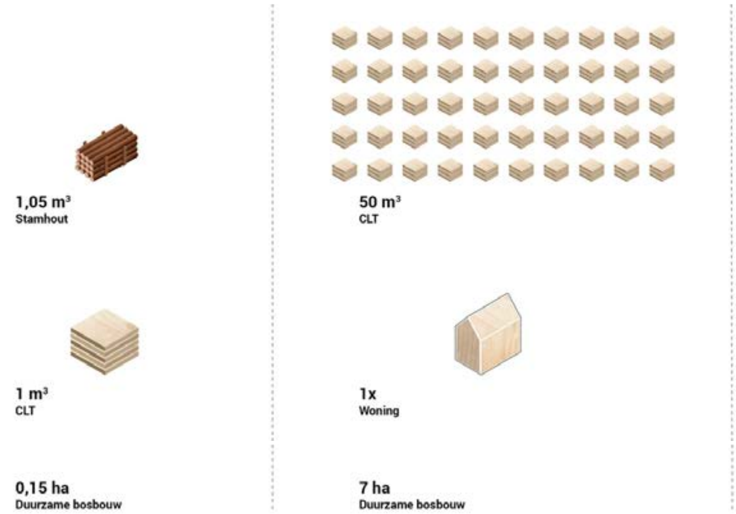


The following observations can be drawn from the projection of harvest

- The results from the calculations of harvest are expressed as specific harvest (m³/ha) and are multiplied by the area of MFL. As the area of MFL is set to increase in the future (**Table 4-1**) so will the harvest in th category. This is the main driver in the evolution of projected harvest.
- The projected harvest has peaked in 2020 (as has the evolution of MFL). The harvest is expected to remain fairly constant for the duration of the CP.
- In order to compare the measured harvest of historic data and the projected harvest the harvest linked t land use change from forest has been subtracted from the measured harvest.

fig. 24: Administration de l'environnement. (2019). National Forestry Accounting Plan Luxembourg. https://environnement.public.lu/content/dam/environnement/documents/natur/forets/NFAP-Luxembourg-2019-review.pdf



Een alternatief
Door minerale bouwmaterialen te vervangen door biobased bouwmaterialen wordt de uitstoot van CO2 geminimaliseerd. Sterker nog: in biobased materialen kan CO2 voor lange tijd worden opgeslagen, misschien wel voor enkele honderden jaren. Daardoor wordt CO2 onttrokken aan de atmosfeer. Studio Marco Vermeulen heeft becijferd dat de bouw van 1 miljoen woningen op conventionele wijze gepaard gaat met 55 Mton CO2 emissie. Met de keuze van biobased materialen kan die hoeveelheid CO2vermeden worden en tegelijkertijd kan er 45 Mton CO2 worden opgeslagen. Een verschil van 100Mton! In tegenstelling tot kostbare opslag onder de Noordzee wordt met deze vorm van CO2 opslag juist waarde gecreëerd in de vorm van woningen. Voor vrijwel alle gebouwdelen bestaan biobased alternatieven zoals houtwol voor isolatie en hennepvezel en vlas in biocomposieten elementen. Maar vooral het gebruik van massief hout als materiaal voor het casco; de wanden, vloeren, trappen en daken, biedt grote kansen. Daarmee kan de bouw een actieve rol vervullen in de strijd tegen klimaatverandering.

fig. 25: Bouwen met bomen. (2019). Studio Marco Vermeulen. https://marcovermeulen.eu/nl/projecten/bouwen+met+bomen/

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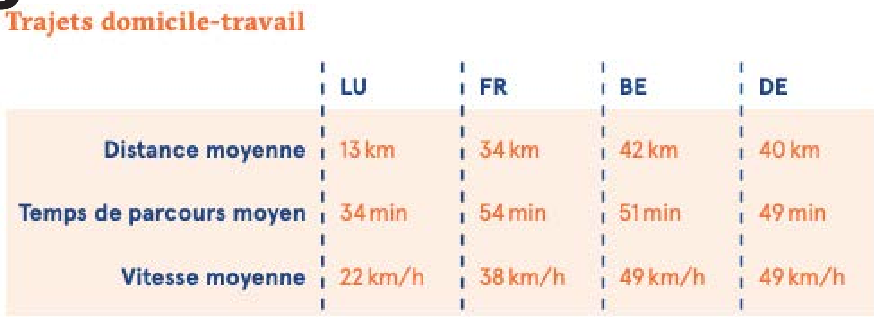
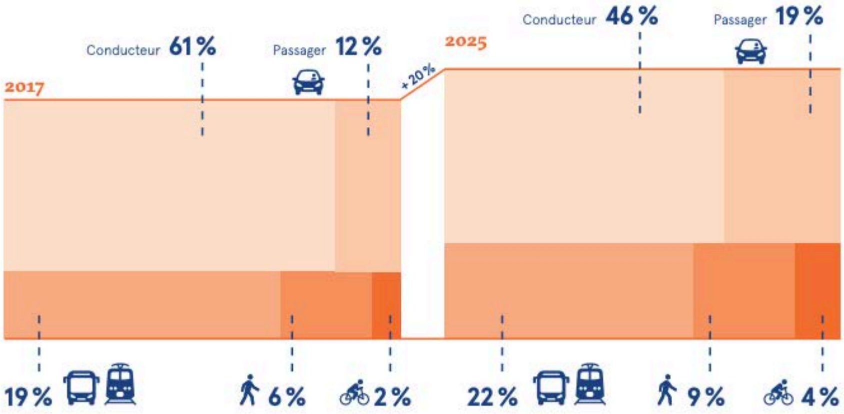


Trajets domicile-travail

	LU	FR	BE	DE
Distance moyenne	13 km	34 km	42 km	40 km
Temps de parcours moyen	34 min	54 min	51 min	49 min
Vitesse moyenne	22 km/h	38 km/h	49 km/h	49 km/h

fig. 26: Ministère du Développement durable et des Infrastructures. (2018). Modu 2.0 - stratégie pour une mobilité durable. Portail Transports. https://transports.public.lu/dam-assets/publications/contexte/strategie/modu2-fr-brochure.pdf



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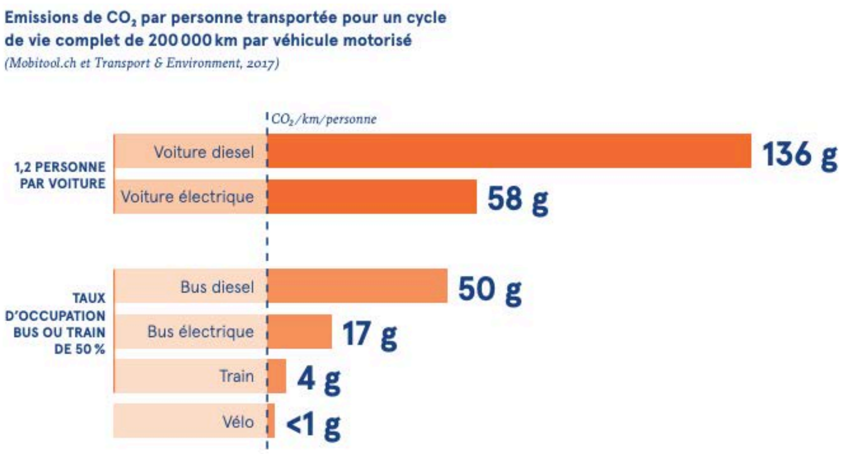

fig. 28: Ministère du Développement durable et des Infrastructures. (2018). Modu 2.0 - stratégie pour une mobilité durable. Portail Transports. https://transports.public.lu/dam-assets/publications/contexte/strategie/modu2-fr-brochure.pdf

fig. 29: Ministère du Développement durable et des Infrastructures. (2018). Modu 2.0 - stratégie pour une mobilité durable. Portail Transports. https://transports.public.lu/dam-assets/publications/contexte/strategie/modu2-fr-brochure.pdf

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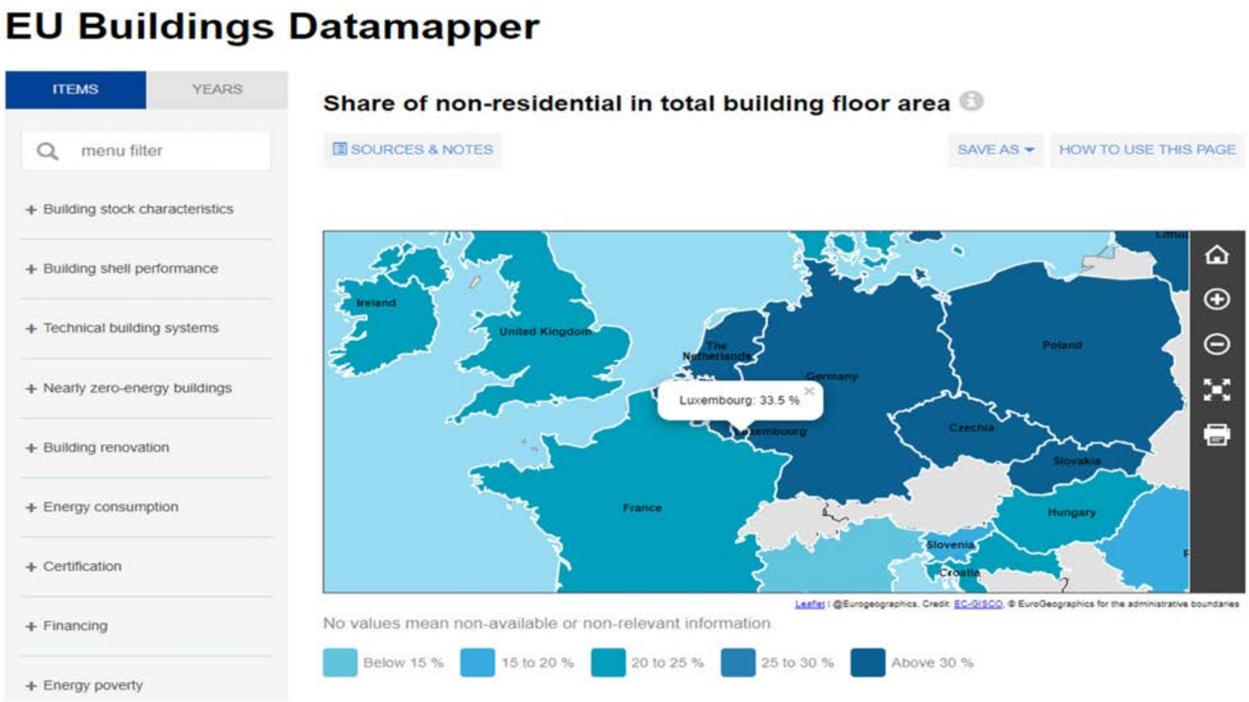

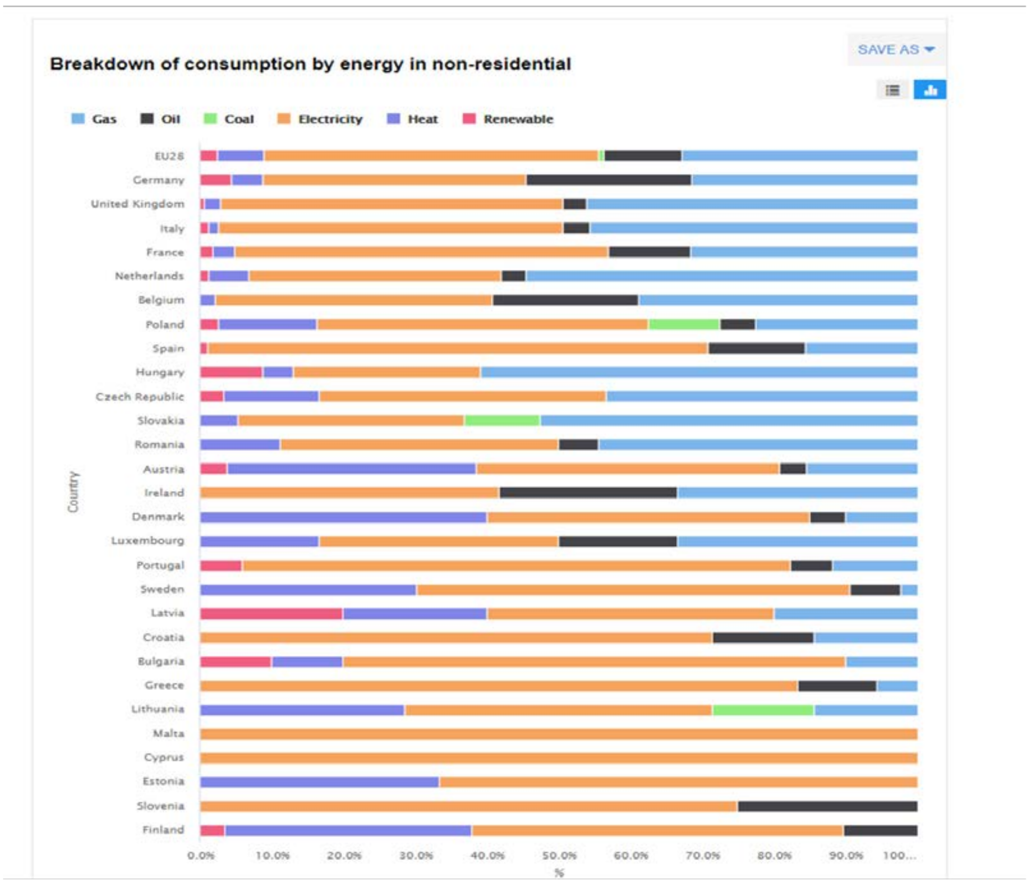

fig. 31: European Commission. (2013). EU Buildings Datamapper https://ec.europa.eu/energy/eu-buildings-datamapper_en

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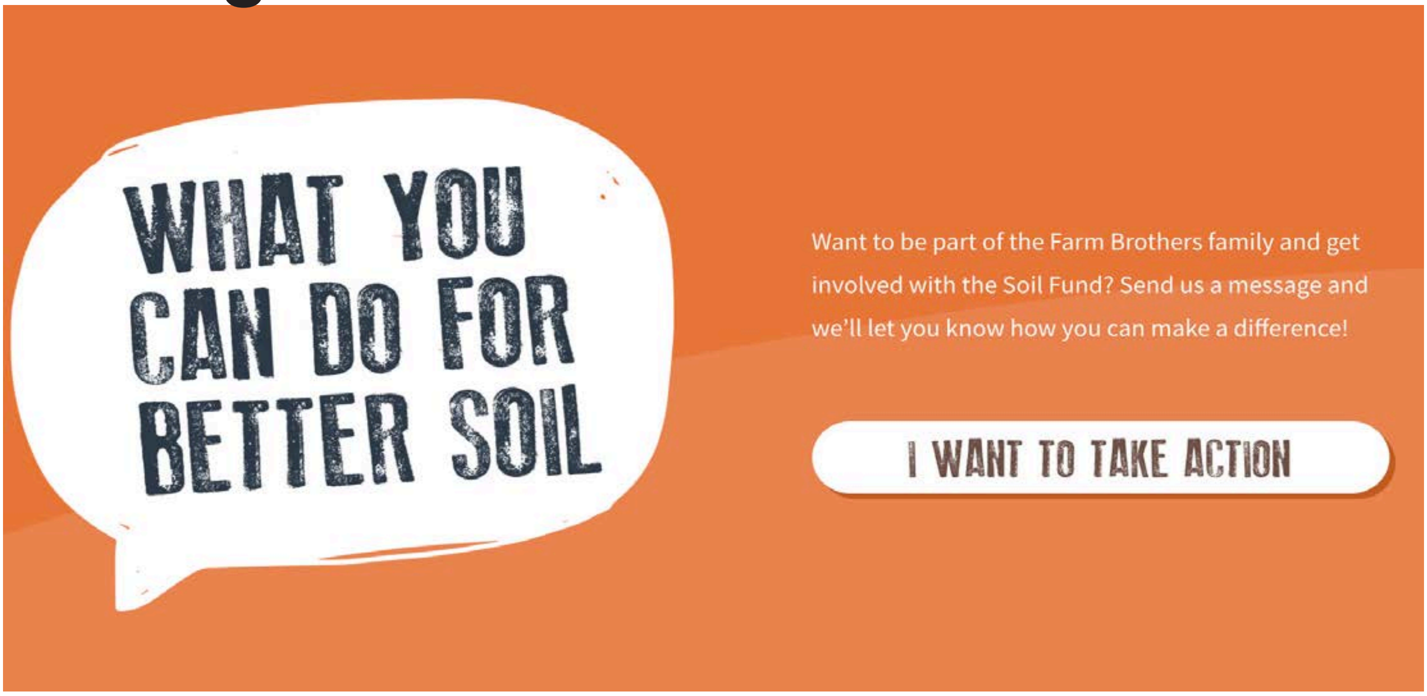

fig. 32: Soil Matters. (2018). https://www.makesoilmatter.com/

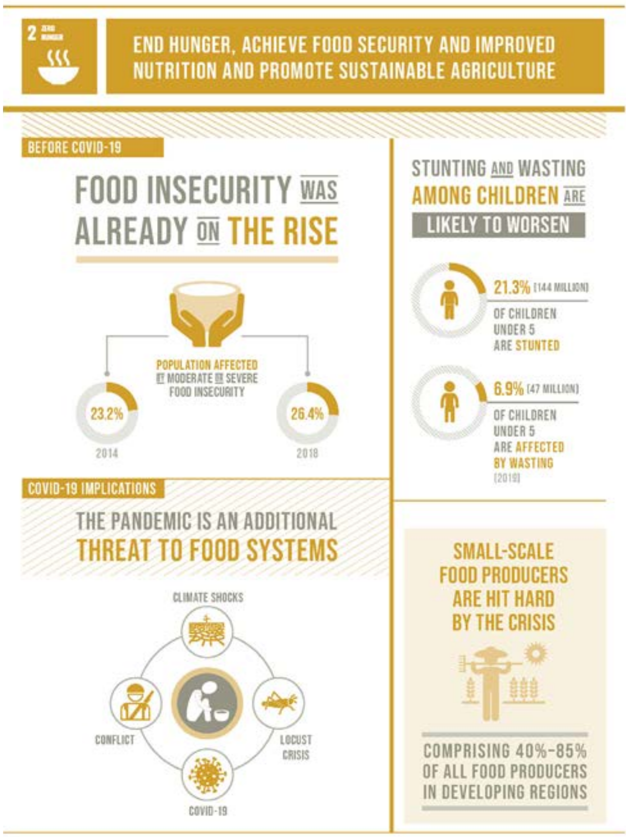

fig. 33: European Commission. (2013). EU Buildings Datamapper https://ec.europa.eu/energy/eu-buildings-datamapper_en

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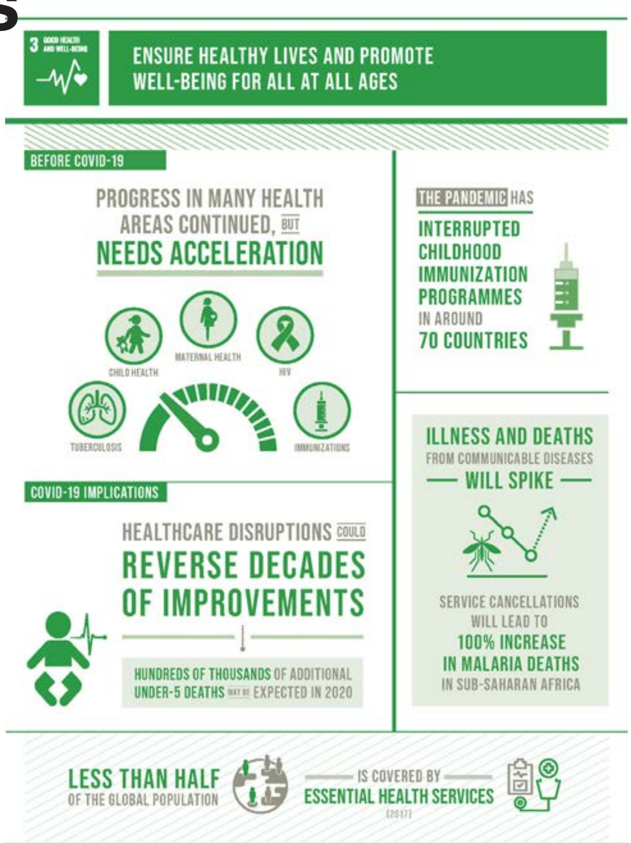

fig. 34: European Commission. (2013). EU Buildings Datamapper https://ec.europa.eu/energy/eu-buildings-datamapper_en

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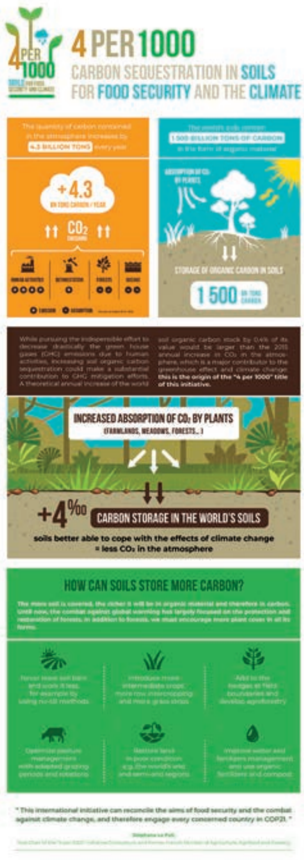

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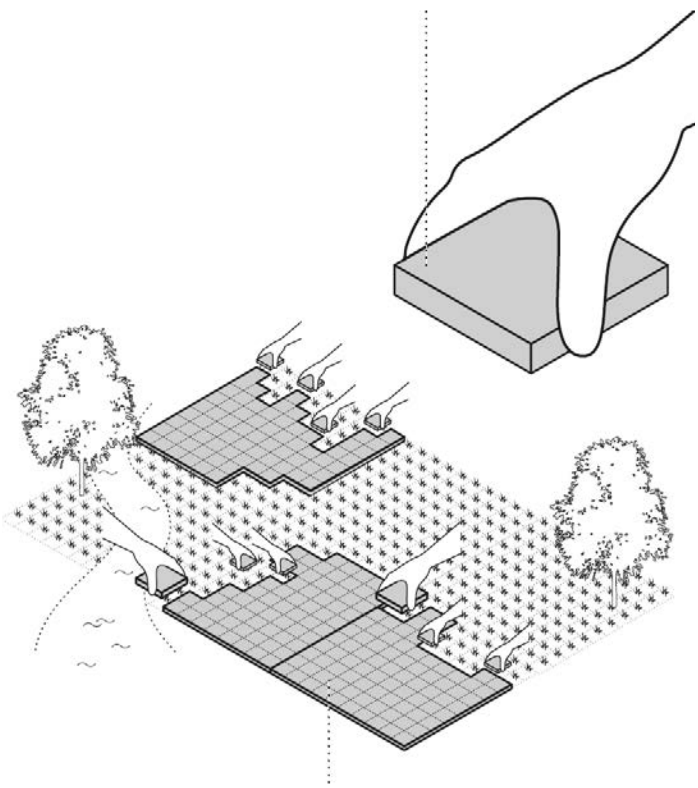

fig. 37: Departement Omgeving, Vlaanderen. (2020). Werkboek proeftuinen Ontharding. https://omgeving.vlaanderen.be/werkboek-en-onthardingsfora

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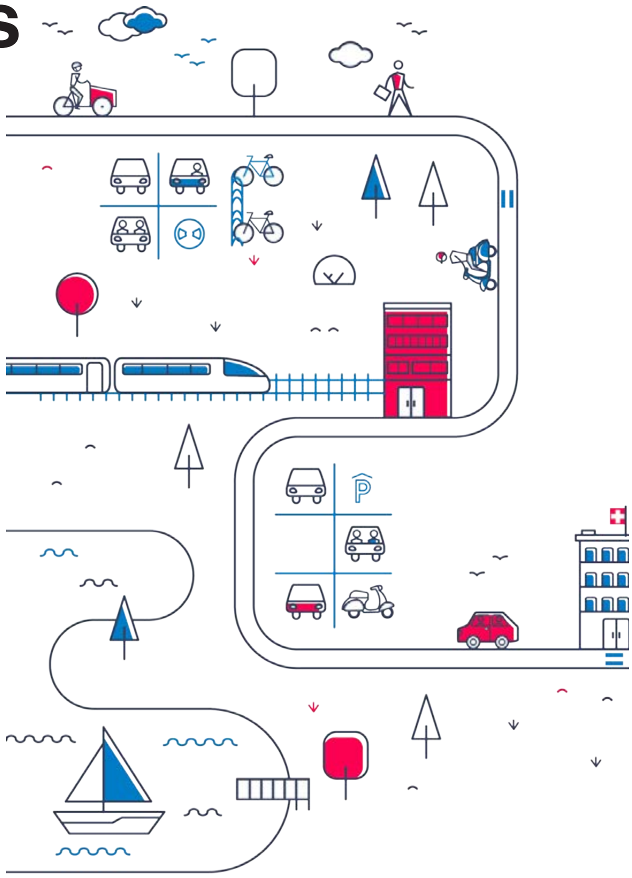

fig. 38: Fairpark. (2020). Explore. https://fairpark.io/en/make-a-tour/

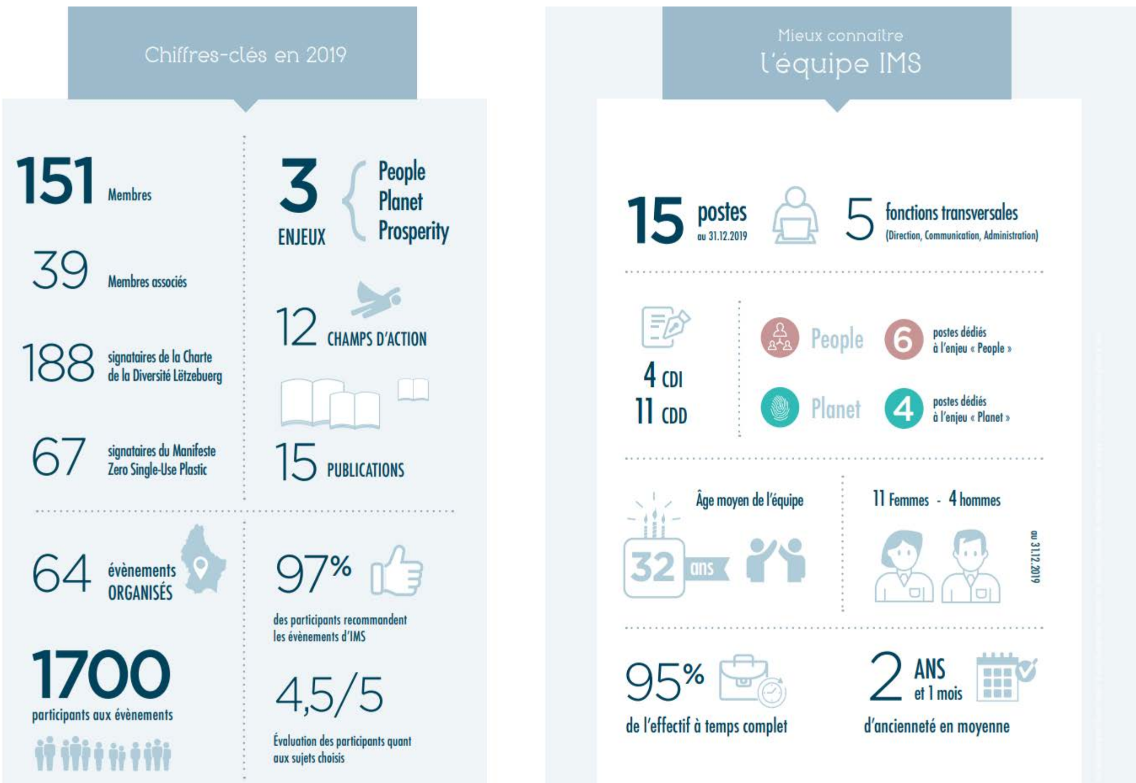

fig. 39: IMS Luxembourg. (2020). Rapport d'activité 2019. https://imslux.lu/assets/publication/78/Rapport_2019_BD%20(1).pdf

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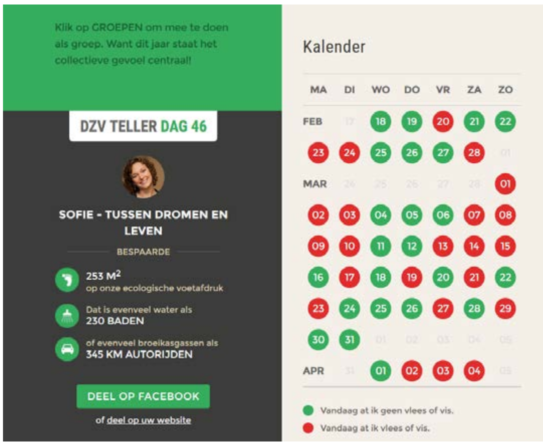

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fig. 41: True Price World Map. (2020). https://trueprice.org/

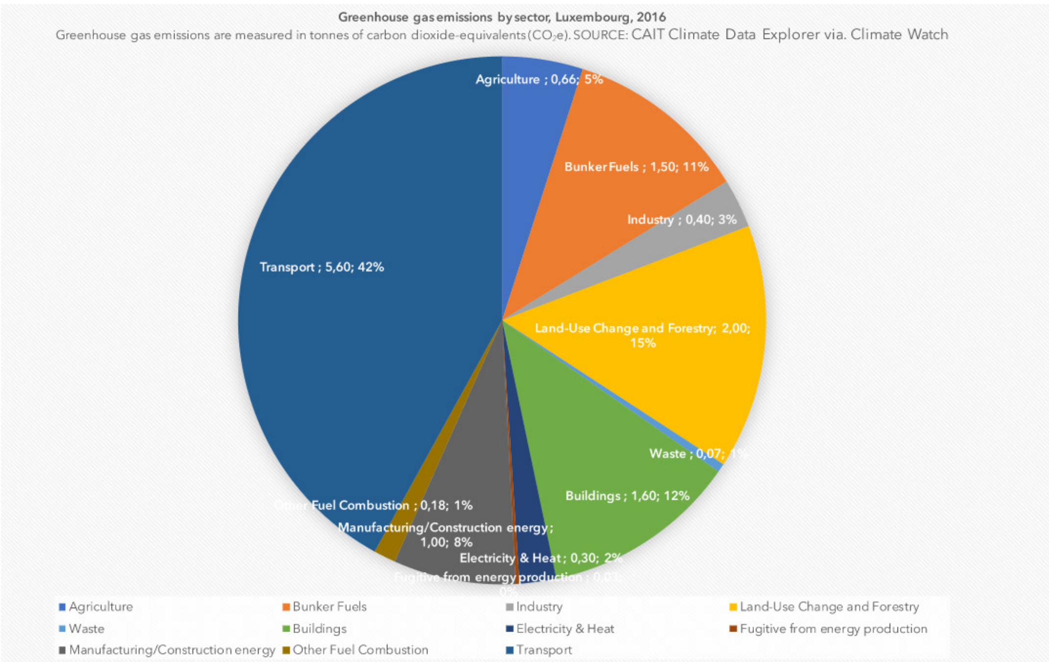

fig. 42: greenhouses gas emissions by sector, Luxembourg. (2016).

IMAGES

5.4 Images

image 1: Nathan, P. (photographer). (2015). Luxembourg aerial view [photograph]

image 2: Cropland. (2019). [photograph]. https://www.outdooractive.com/en/hikes/luxembourg/hikes-in-luxembourg/1427076/

image 3: Soil degradation. (2019). [photograph]. https://agriculture.public.lu/dam-assets/publications/ma/actualit%C3%A9sasta/J-Deckers-Sol-approche-holistique-Journee-aca-20191211.pdf

image 4: Pastures and livestock. (2014). [photograph]. http://www.grengland.lu/sites/default/files/files/iglt_2014_fr.pdf

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image 6: Luxembourg first to ban Glyphosate (2020). [photograph]. https://delano.lu/d/detail/news/luxembourg-first-ban-glyphosate/209110

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image 8: Compost application. (2017). [photograph]. https://fieldcropnews.com/2017/08/ontario-field-crop-report-august-10-2017/

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image 9: Cover crop. (2020). [photograph]. https://hellohomestead.com/garden-and-farm/page/5/

image 13: Scuto, D., Caregari, L., & Knebeler, C. (2010). Belval : Passé, présent et avenir d'un site luxembourgeois exceptionnel (1911 - 2011). Éd. Le Phare.

image 10: Environment management. (2020). [photograph]. https://www.cafre.ac.uk/2020/11/27/environment-management-notes-december/

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image 12: Nathan, P. (photographer). (2015). Luxembourg aerial view [photograph]

image 16: Nathan, P. (photographer). (2015). Luxembourg aerial view [photograph]

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image 17: Craze, M. (2020). InnovaFeed will build US insect plant with agribusiness giant ADM. Undercurrent News. https://www.undercurrentnews.com/2020/11/19 innovafeed-will-build-us-insect-plant-with-agribusiness-giant-adm/

image 20: Planteur Volontaires. (2020). Planteurs Volontaires - On plante ensemble ? http://planteurs-volontaires.com/#home

image 18: Le Sillon Belge. (2019). Planter 4.000 km de haies ou 1 million d'arbres. https://www.sillonbelge.be/5187/article/2019-11-25/planter-4000-km-de-haies-ou-1-million-darbres

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OTHER TABLES

5.6 Other tables - reimagining transport

CO_2 Reduction by 3days work from home policy for national employees

		Unit
Number of national employees	272.100,00	person
Considering 90% will commute daily to work	244.890,00	person
Estimated daily trips to and from work	489.780,00	person trips
Weekly trips	2.448.900,00	person trips
Total number of trips saved per week	661.203,00	person trips
Total number of private vehicle trips saved per week	482.678,19	person trips
Total number of trips saved per year	22.685.874,93	person trips (4)
Car occupancy	1,16	pax/veh (3)
Total number of veh. Trips saved per year	19.556.788,73	veh
Estimated average travel distance for national employees	26,00	km (3)
Total number of vehicle*Km saved per year	508.476.507,05	veh*km
Emission per vehicle*km	0,136	Kg CO_2/Km/person (3)
Annual emissions reduction Kg	80.217.253,75	kg CO_2
Annual emissions reduction Tons	80.217,25	Tons CO_2
Total emissions annual reduction per national employee per year	294,81	kg CO_2/national employee /year
Total emissions annual reduction per national employee per year	0,295	Tons CO_2/national employee /year

Number of vehicles removed from road by 3day work from home policy

		Unit
Number of national employees	272.100,00	person
Considering 90% will commute daily to work	244.890,00	person
Estimated daily trips to and from work	489.780,00	person trips
Weekly trips	2.448.900,00	person trips
Total number of trips saved per week	661.203,00	person trips
Total number of private vehicle trips saved per week	482.678,19	person trips
Total number of trips saved per year	22.685.874,93	person trips (4)
Car occupancy	1,16	pax/veh (3)
Total number of vehicles removed from the road per week	416.101,89	vehicle
Total number of vehicles removed from the road per working day	83.220,38	vehicle
Total number of vehicles removed from the road per year	19.556.788,73	vehicle

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5.6 Other tables - reimagining energy

Office surface		Unit		
Number of daily cross-boarder commuters	200.000	person	Grand-Duché de Luxembourg. (n.d.). Labour market overview. Le portail des statistiques	(1)
Number of Luxembourg workforce	272.000	person		
Office Space per Working Person	20	m²/pers (total)		
Offi	73%			
Sparable office space	5,4	**m²/pers**		
in percent of office space	27%			
Sparable office area for all commuters	1.080.000	m²		
Sparable office area for all national employement	1.468.800	m²		
Energy				
Useful heating demand office building (Standard)	100	kWh/m²	Maas, S., Scholzen, F., Thewes, A., & Waldmann.	(2)
Enedenergie electricity heating - (Standard)	33,3	kWh/m²		
Enedenergie Gas- (Standard)	100,0	kWh/m²		
Enedenergie electricity heating - (Standard)	84.960	MWh		
Enedenergie Gas- (Standard)	254.880	MWh		
Electricity grid carbon intensity	513	g-CO_2/kWh	Moro, A., & Lonza, L. (2018). Electricity carbon intensity in European Member States: Impacts on	(3)
Erdgas emissionfactor	201,6	g-CO_2/kWh		
Operation energy spared (t CO2)				
Gas heating (Standard)	51	kt CO_2		
Electrical heating (COP =3) (Standard)	44	kt CO_2		
50% Gas - 50% Electrical heating (CPO=3)	47	kt CO_2		
50% Gas - 50% Electrical heating (CPO=3)	0,10	tCO_2/capitaworkforce/yr		
Residential, commercial and institutional combustion (2018)	1.640	kt CO_2eq	Inventaire des Gaz a effet de serre. (2020, April 17). Portail de l'environnement - emwelt.lu - Luxembourg.	(4)
Operation energy spared (% total 2018)				
Gas heating (Standard)	3,1%			
Electrical heating (COP =3) (Standard)	2,7%			
50% Gas - 50% Electrical heating (CPO=3)	2,9%			
Complementary Information				(fig 30-31)
Share of non-residential in total building floor	*33,50%*	*549,4*		
Share Residential	*66,5%*			
Share office ?	*20%*	*328*		
		65,6		
		0,72		

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