Beyond Lux(e)!

02.01.2021

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Foreword

Luxembourg is in transition, not because this consultation declares this, or because of the Paris agreements, or because of COVID19. Luxembourg is in transition because the world's future is uncertain. We see increasing signs that the current way we organise, work and think about our energy, mobility, water, waste, and food systems is no longer sustainable. The CO_2 levels of our fossil fuel-based economy are symptoms of the unsustainability of our societal systems. 'External trends' like COVID19 forced Luxembourg into reckoning with these dependencies. At the same time, transitions are already well underway. Diverse societal actors are increasingly aware of the urgency and are developing alternative initiatives. For example, communities that prohibit cars in their streets transform their street into a living room, where children can play safely and where parking places become a green oases for butterflies and insects.

The Department of Spatial Planning of the Ministry of Energy and Spatial Planning recognises that conventional planning approaches will not be sufficient in times of transition. They have therefore commissioned an urban-architectural and landscape consultation to illustrate how spatial design and planning can facilitate a transition towards a zero-carbon emission and a resilient society in 2050. Including external expertise helps to expand your perspective on the transition and challenge biased and short-sighted practice. For example, rather than exclusively focusing on the CO_2 neutral target this approach considers this one aspect of the transition towards a regenerative resilient Luxembourg functional region.

To this end, our consortium comprises a multidisciplinary approach. We believe that a design-lead process fundamentally requires collective understanding of transition. From this, we consolidate a clear and imaginative spatial imaginary, which we then test through a rigorous methodology that combines the needs and opportunities per theme and the synergies amongst them. We communicate these efforts and learnings in our report for Phase 1 where we expose why, how, and sketch what we expect to obtain in future. Fundamental to this approach is the understanding that this consortium does not present a plan, but rather a methodology that is co-produced, and iterative, with a permeable-flexibility that absorbs unpredictable, future variables to promote resilience and robustness in the long term.

Beyond Lux(e)!

What transition?

1

Defining transition

This is not the first time the human race is moving through immense transition. We need not look much further than the beginning of the last century, with the advent of the automobile and its impact on the shape and speed of our cities, lifestyles, and consumption habits. We cannot plan transitions, as this effort would require a collective force beyond our capacity to influence and organize. What we can control is the learning process concerning what new structures we need but also what structures we need to destabilise to allow room for emerging alternatives, and other structures to emerge. In the historic mobility transition, we recognised that we needed different infrastructure to support the automobile. Whereas horses need places to rest and eat, the automobile needs refuelling and different kinds of roads. This new means of transportation also cultivated different habits and perspectives on transportation. Quantitative indicators do not exclusively drive transitions. Bertha Benz used the first car on a fuel-burning engine because she wanted to visit her family. During this first road trip, she identified novel inventions which would ultimately improve the design. Learning-by-doing and doing-by-learning was integral to this transition, and will be in the transition from fossil fuel-based systems of today towards the resilient and (re)generative systems of tomorrow.

We base this methodology of (re)generation on lessons from historical transitions. This methodology propels a shift beyond quantitative indicators such as CO_2 reduction targets, because these reinforce a focus on the current system's unsustainable qualities, by creating technology that reduces pollution. If Henry Ford was focusing on the how to make the horse carrier more efficient, he would never have designed that first car. Instead, he would have looked at the kind of food the horse was eating, or other optimisation strategies. People do not relate to CO_2 targets, they want safe places for their kids to play, health air to breathe, and quality time instead of time squandered in traffic jams. Carbon reduction is an important policy goal, and KPIs can track progress; however, (re)generation requires a complete paradigm shift.

Exclusively focusing on the CO_2 numbers will not build a narrative that people can relate to, and inspire motivation to change their habits. The methodology we propose combines two narratives on one x-curve:

1. The first narrative builds upon emerging alternatives that illustrate how a regenerative Luxembourg functional region works, what it will look like, what kind of food will be consumed, and how people will move in the region, etc. This narrative is created based on a retrospective process that serves to identify what is required, step-by-step to reach a regenerative, nature-positive Luxembourg.

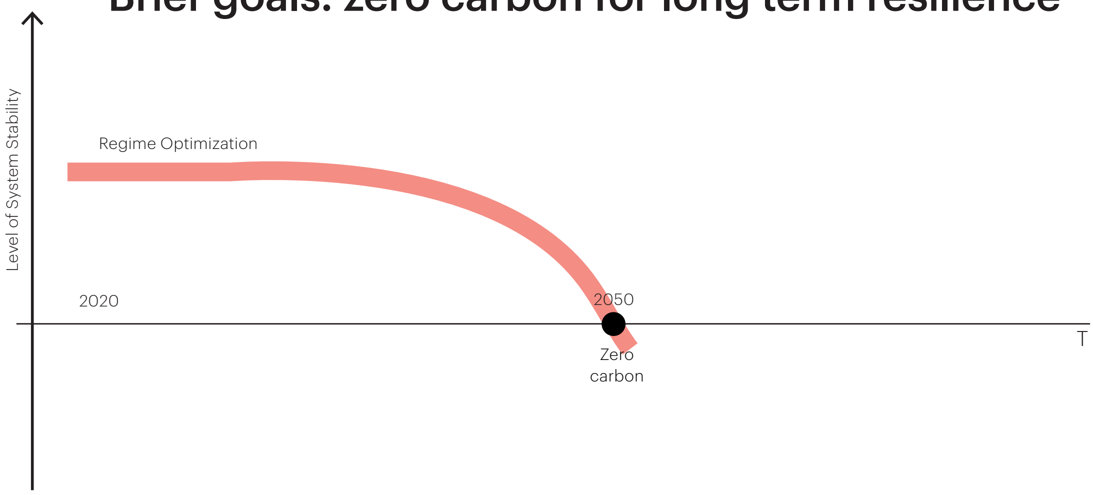
2. The second narrative builds upon what we already understand will not be part of the future scenario, because current practices are simply too CO_2 intensive. For example, this future will seek to minimise car-dependent systems and meat-based diets. We base this predicted narrative on current knowledge and will include exit strategies for economic impact, because losses are also important to manage in system transitions.

Transition
- Long term (1-2 generations, 20-50 years)
- Radical and structural change
- System level (region, sector, city)
- High degree of complexity and insecurity

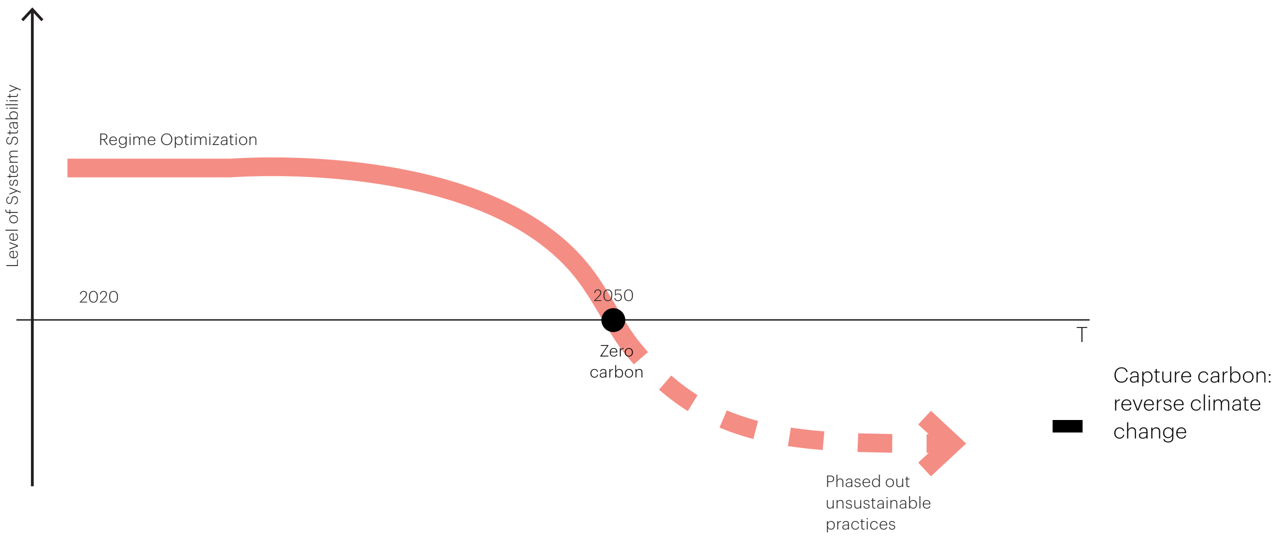
Sustainability transition
"... a process of radical transformation towards a more sustainable society, as an answer to various persistent problems in modern societies."

(Grin, Rotmans & Schot 2010)

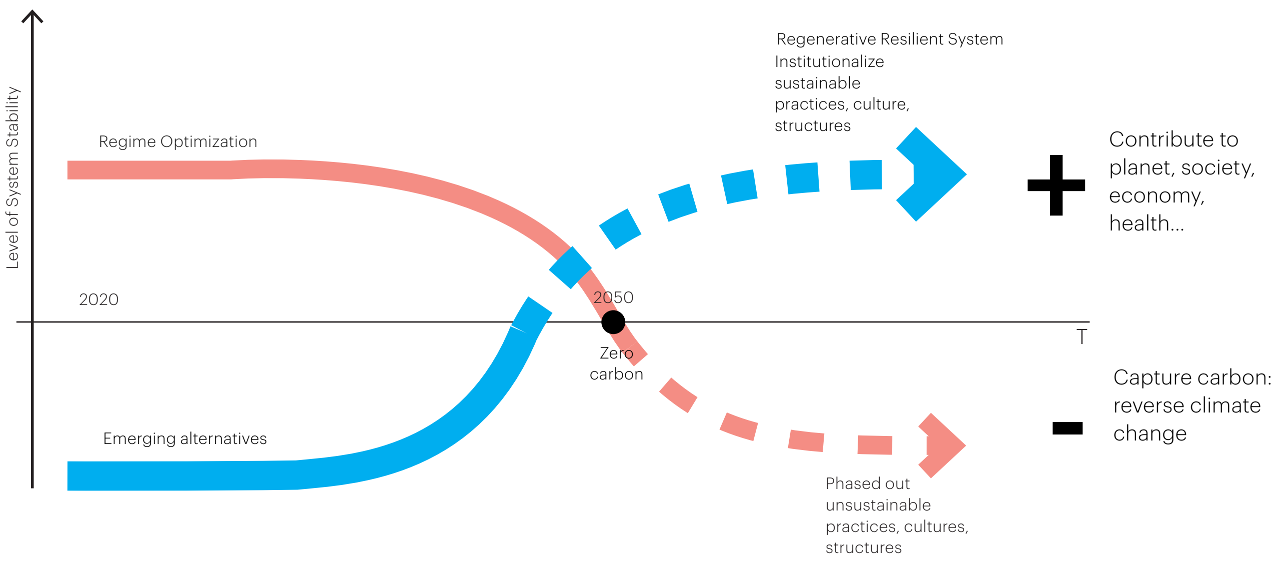
Brief goals: zero carbon for long term resilience



...what is beyond zero carbon?



(re)generative approach to contribute to planet



Our approach

Our design-led transition governance approach will help the Department of Spatial Planning of the Ministry of Energy and Spatial Planning to identify the transitions already underway and how these can be included as regenerative metrics that work alongside CO2 reduction.

Regenerative Systems
"... socio-ecological systems that enhance the ability of living beings to coevolve.
"

Regenerative Development
"... co-production though local capacity building to achieve maximum systemic leverage and support through time."

(based on: Mang & Reed 2020)

We will deliver a process design that started to be implemented and can be continued to support the emerging alternatives to become the norm and phasing out unsustainable practices by including actions that are already happening within the interventions of the process.

We developed this design-led transition-governance approach within a consortium that consists of experts of each of the transition themes, as well as landscape, design, and transition governance experts. Our consortium believes that our role as experts and designers must also change due to transition dynamics at play. This has informed the co-production of this methodology, which will form the starting point of a co-production process engaged with local actors. Therefore, we aim to facilitate the transfer of this approach as part of the upcoming phases. We see this as our role: as visualizing the how the transition towards a regenerative and resilient Luxembourg functional region can be, and supplementing this with metrics that should be accompanied by trade-offs in terms of positive and negative impact; as food, energy, water, mobility, and Luxembourg's waste system are all in transition at the same time. In the methodology we propose, we illustrate that the actions, metrics, and governance can be included in one co-production process that, in its engagement of societal actors, will accelerate the transition of the region.
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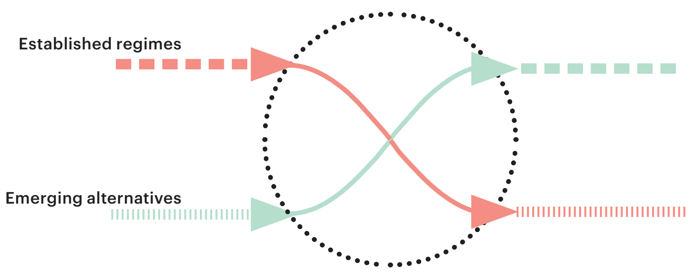
Mang, P., & Reed, B. (2020). Regenerative development and design. Sustainable Built Environments, 115-141.

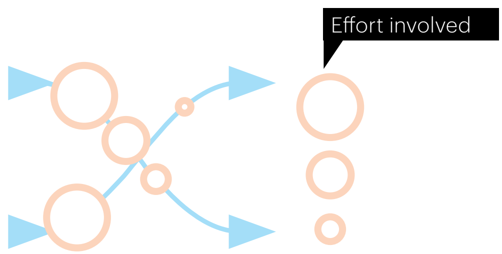
Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability transitions research: transforming science and practice for societal change. Annual Review of Environment and Resources, 42.

Grin, J., Rotmans, J., & Schot, J. (2010). On patterns and agency in transition dynamics: Some key insights from the KSI programme. Environmental Innovation and Societal Transitions, 1(1), 76-81.

Geels, F. W. (2005). The dynamics of transitions in socio-technical systems: a multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). Technology analysis & strategic management, 17(4), 445-476.

Tool to understand what phases out & what phases in





Loorbach et al (2017)

Initiatives

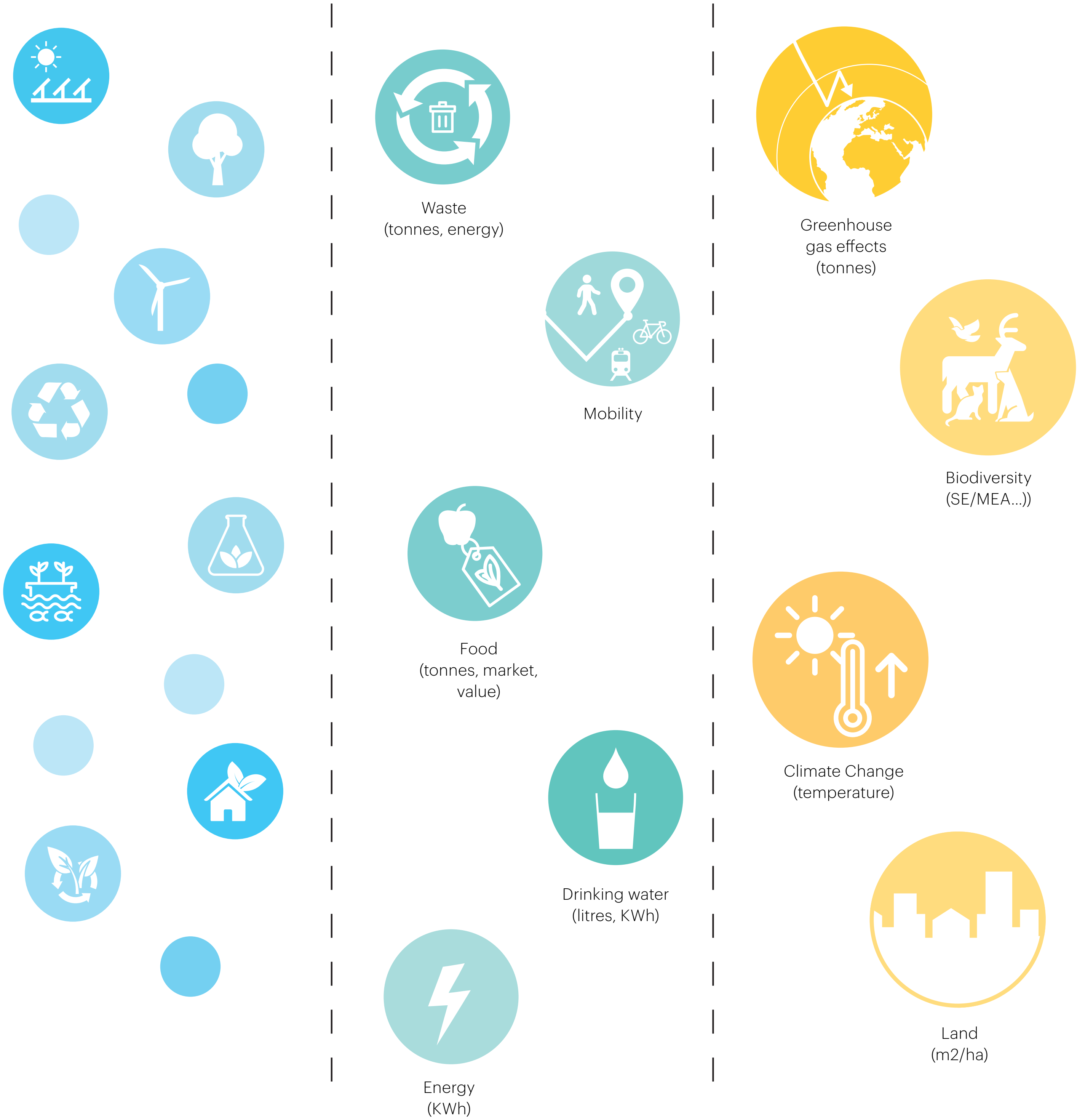
Micro level = “niches“

“Systems” we can change

Meso level = “regimes”

Consequences

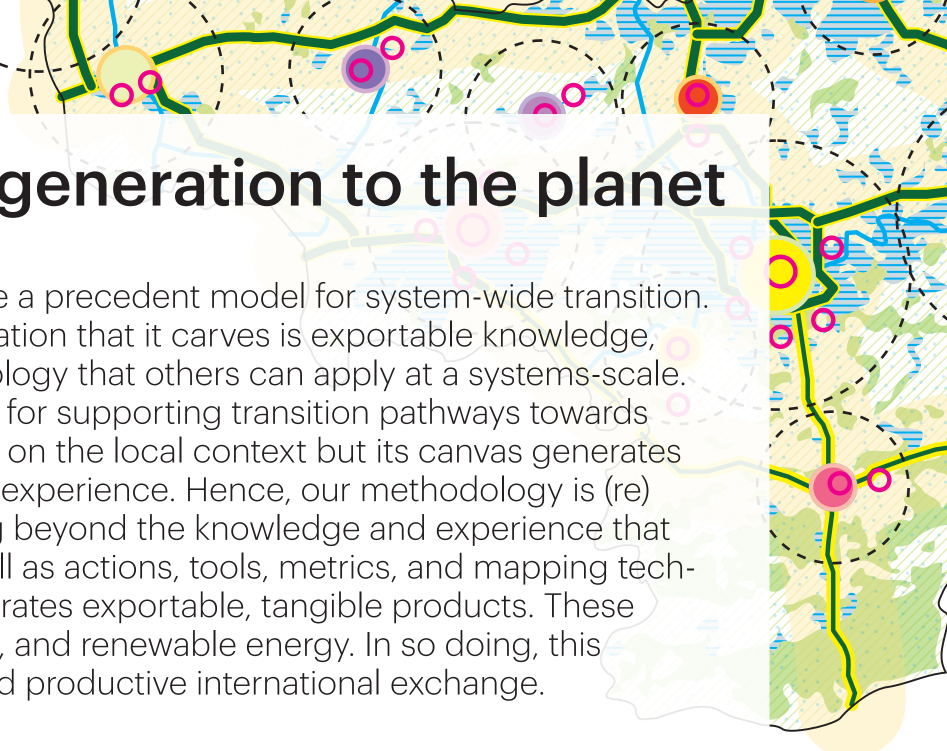
Macro level = “landscape”



beyond lux(e)! vision

Exporting (re)generation to the planet
Actions on Hubs & Network
Contributing to the planet
(re)generative Network
(re)generative Hubs
Phasing the bucket list by 2050

2



Exporting (re)generation to the planet

Beyond Lux(e)! can become a precedent model for system-wide transition. The path towards (re)generation that it carves is exportable knowledge, experience, and a methodology that others can apply at a systems-scale. We provide a methodology for supporting transition pathways towards (re)generation that is based on the local context but its canvas generates exportable knowledge and experience. Hence, our methodology is (re) generative in itself. Looking beyond the knowledge and experience that this project amasses, as well as actions, tools, metrics, and mapping technologies, this process generates exportable, tangible products. These include O2, N2, clean water, and renewable energy. In so doing, this supports a collaborative and productive international exchange.

Two spatial strategies support the vision driving this precedent model:

Hubs

- These integrate the actions for diverse themes, drawing systems into connection and facilitating collaboration
- For example, these might include city hubs where bio-digesters produce energy for the neighbourhood, where water is cleaned and filtered from rainwater collection, and food is produced through aquaponics
- (re)generation hubs will be distributed along urban and rural areas as long as they are well-connected through existing infrastructure

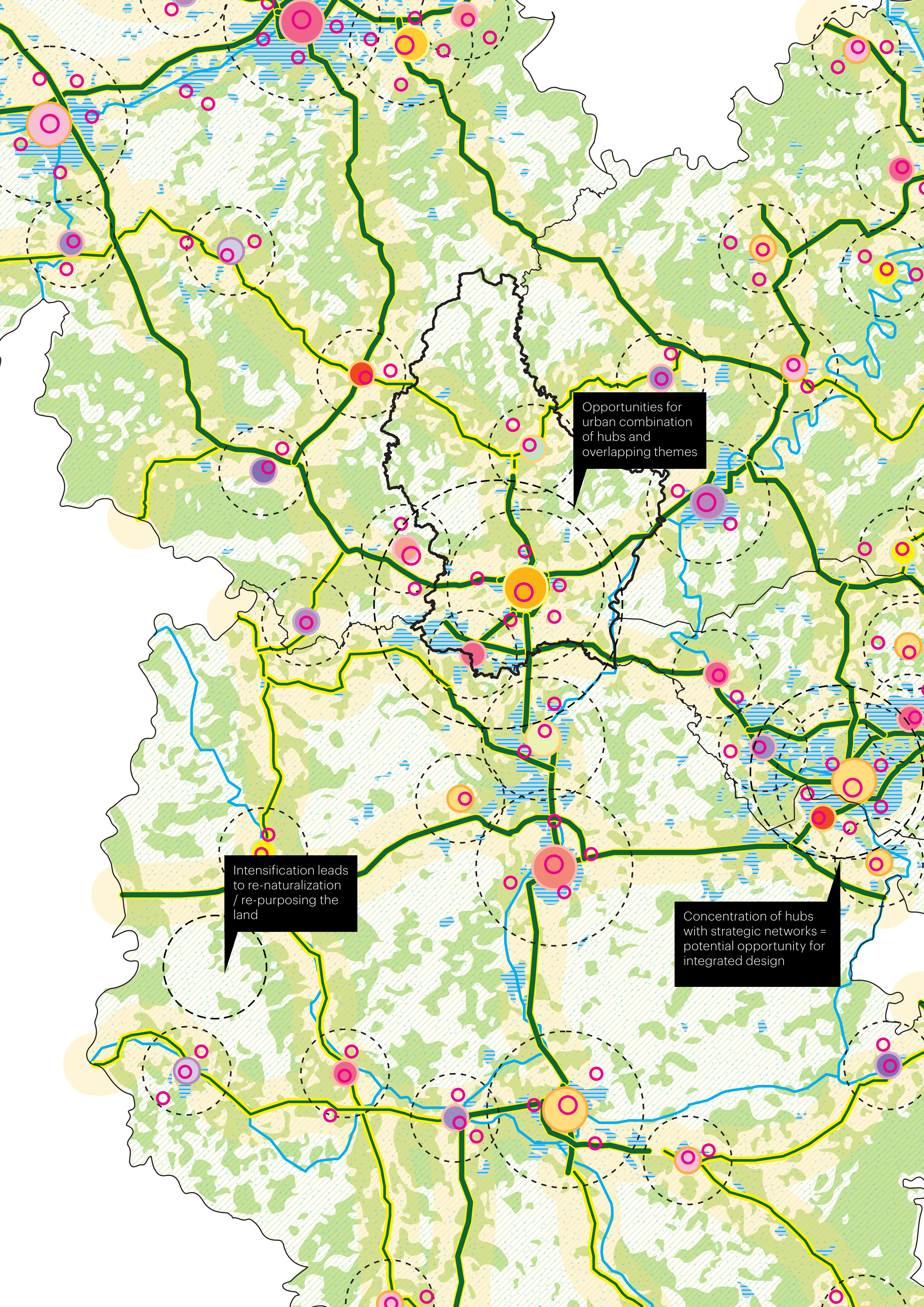
Network

- The buffer, or residual spaces around these connection lines will support activities and spaces for production and distribution. This intensifies the programs, and generates “high lines” of activity
- For example, a highway of heat distribution can run parallel to a bike lane; windmill placement that does not disturb landscapes and urban settlements, but can accommodate vertical farming to intensify plant-based production, etc.

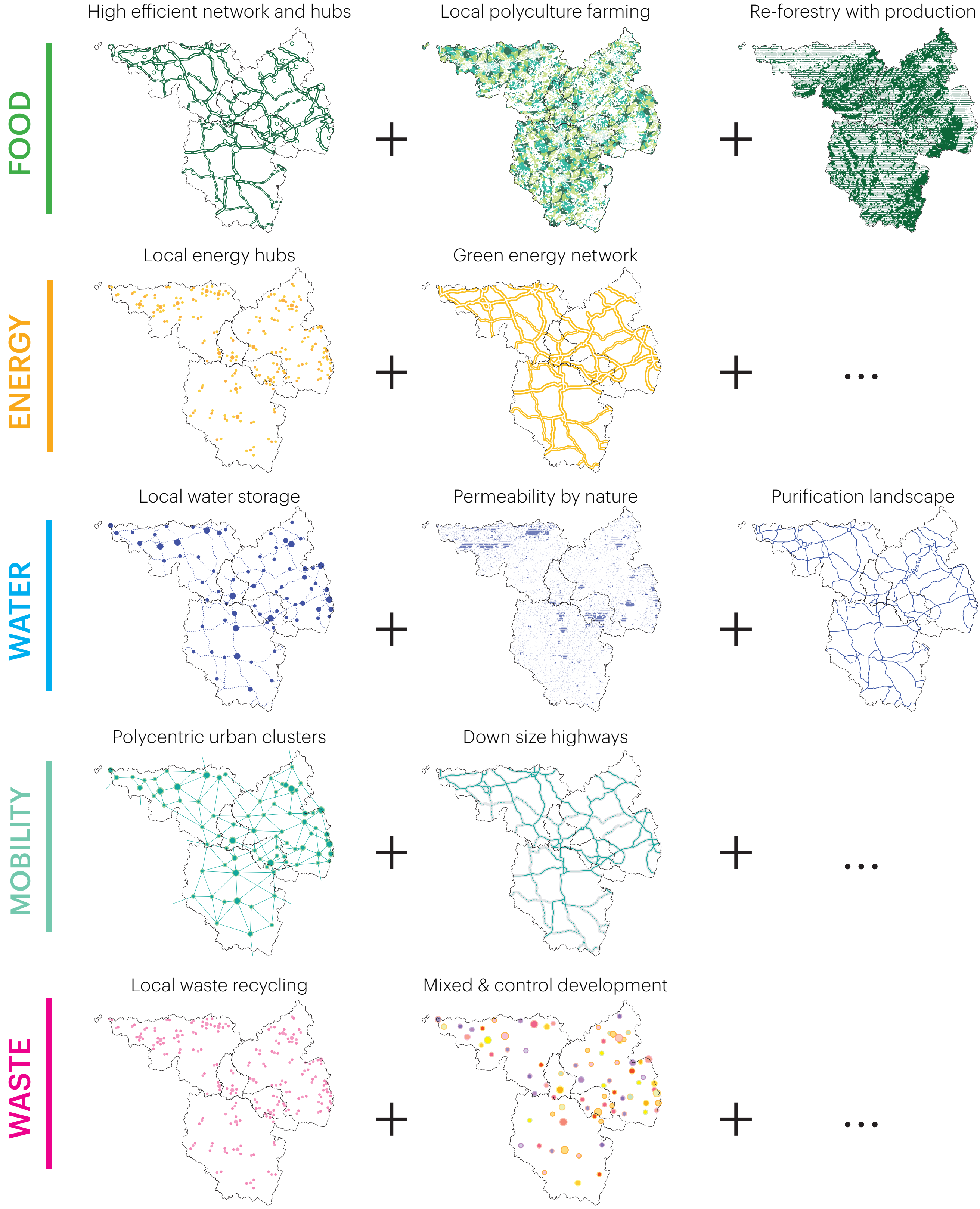
Both strategies contribute to, and have multi-level ambitions. They both facilitate the renaturalization of areas, and involve the repurposing of agricultural land for wild or productive forest, and restore biodiversity corridors, while also intensifying sustainable, local production practices.

(re)generative vision

Forest
Reforestory + organic polyculture farming
Local water treatment
Water permeable surface
(re)generative Network
Polycentric production & consumption
Mix-used urban settlement
(re)generative Hubs

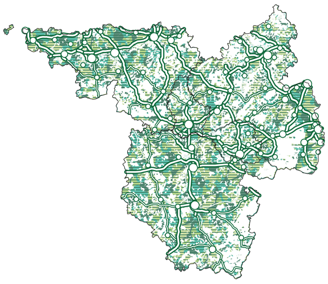

Opportunities for urban combination of hubs and overlapping themes
Intensification leads to re-naturalization / re-purposing the land
Concentration of hubs with strategic networks = potential opportunity for integrated design

Actions on (re)generative hubs and network



Contributing to the plant

Food action map

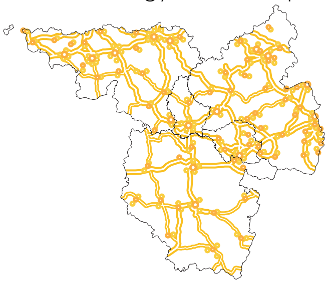
=  =

29% CO2e
Reduction resulting of changing diets, localized system and agroecology

\+ **27%** back to nature
repurposing of pastrue land to rebuild biodiversity and climate resilience

\+ **50%** better water
reducing N2 pollution of groundwater by sustainable farming

Energy action map

=  =

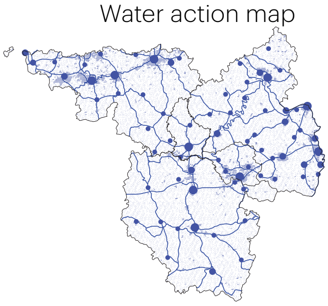
68% CO2e
reduction on the functional area

\+ **160%** land use
Optimization of landuse by combining energy to other productions (ie food)

\+ **0%** energy waste
co-gen or reuse of heating or other "waste" energy

into domestic heating

Water action map

=  =

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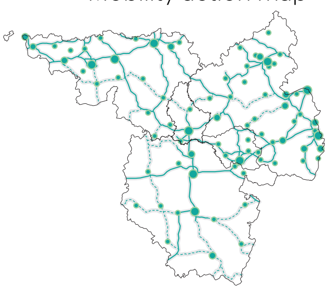
\+ **3,4%** soil sealing
reverted artificial, waterproof land into permable surfaces

\+ **80%** purification
by reducing excessive nutrient load

Mobility action map

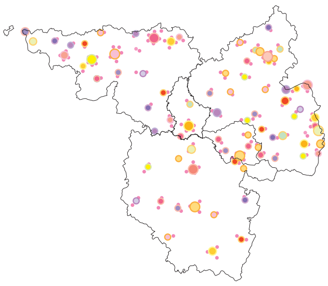
=  =

6% CO2e
Reduction resulting of sustainable transport of inhabitants

\+ **0** fatalities
reduction in casualities by making slow streets

\+ ...

Waste action map

=  =

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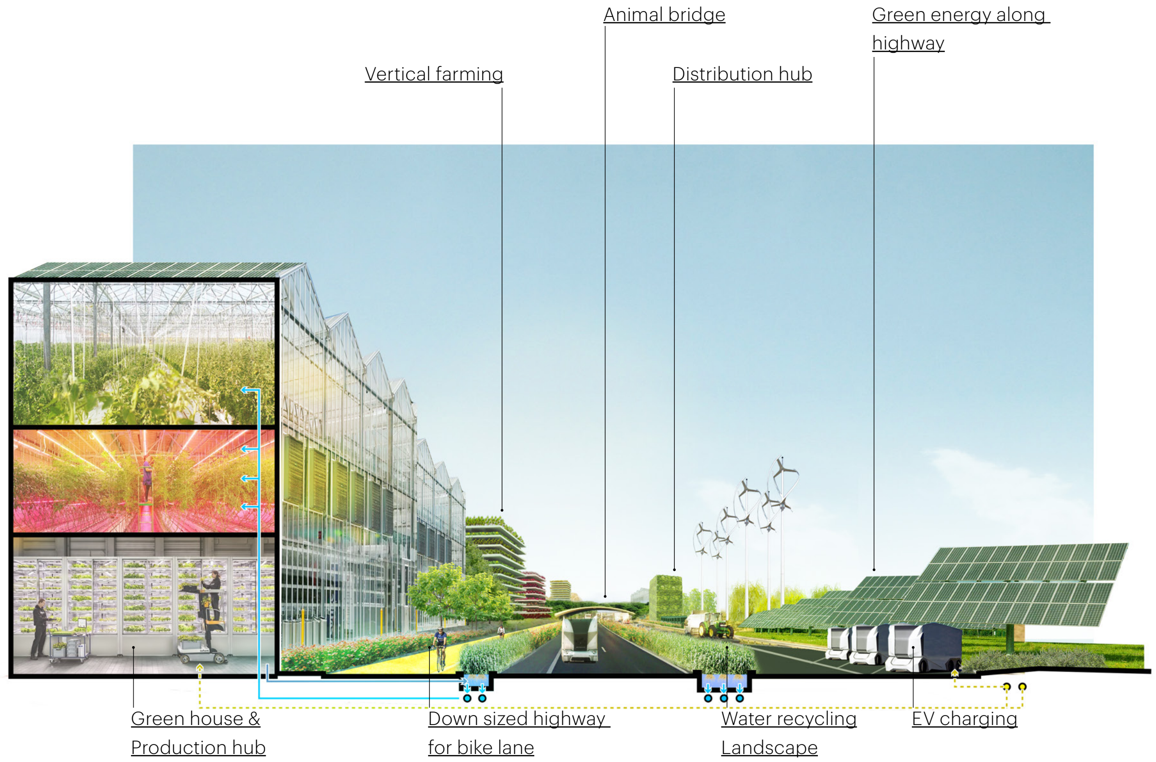
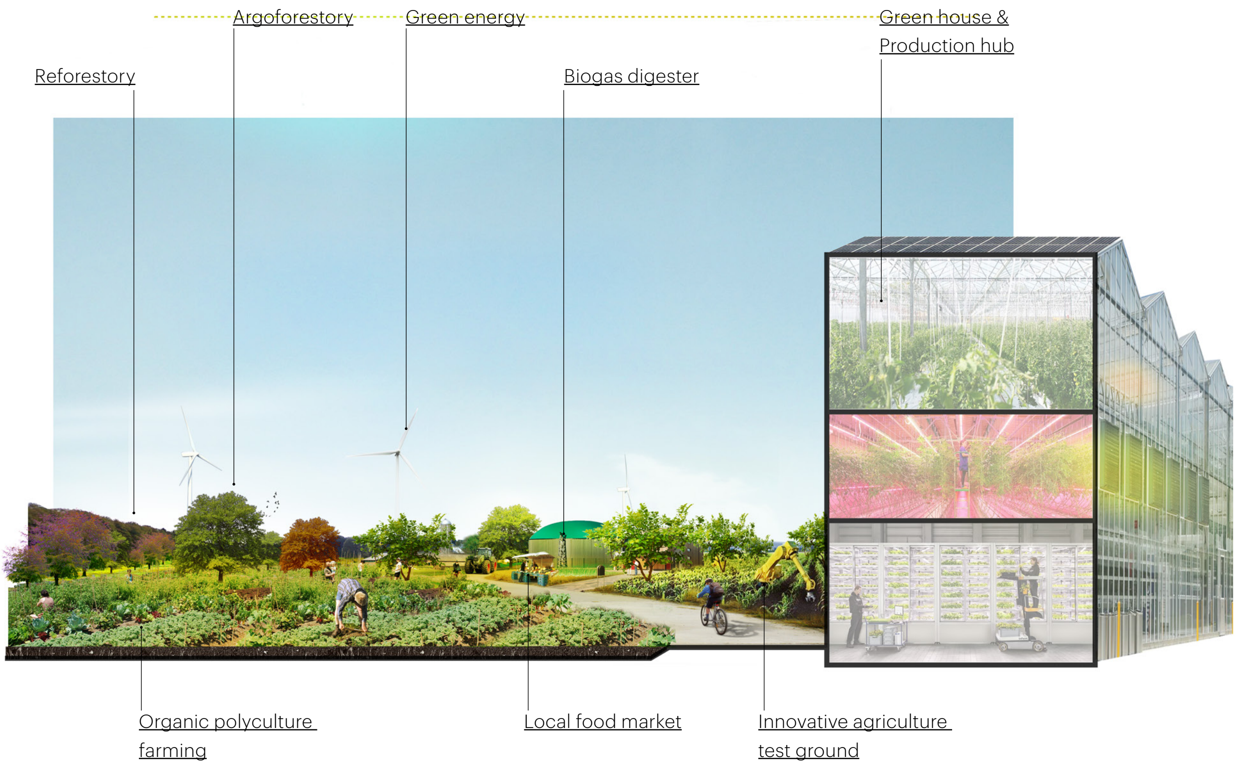
(re)generative Network

Intensifying the network



Collage Hyper Highway - Producing, Distributing, Storing (preliminary study)

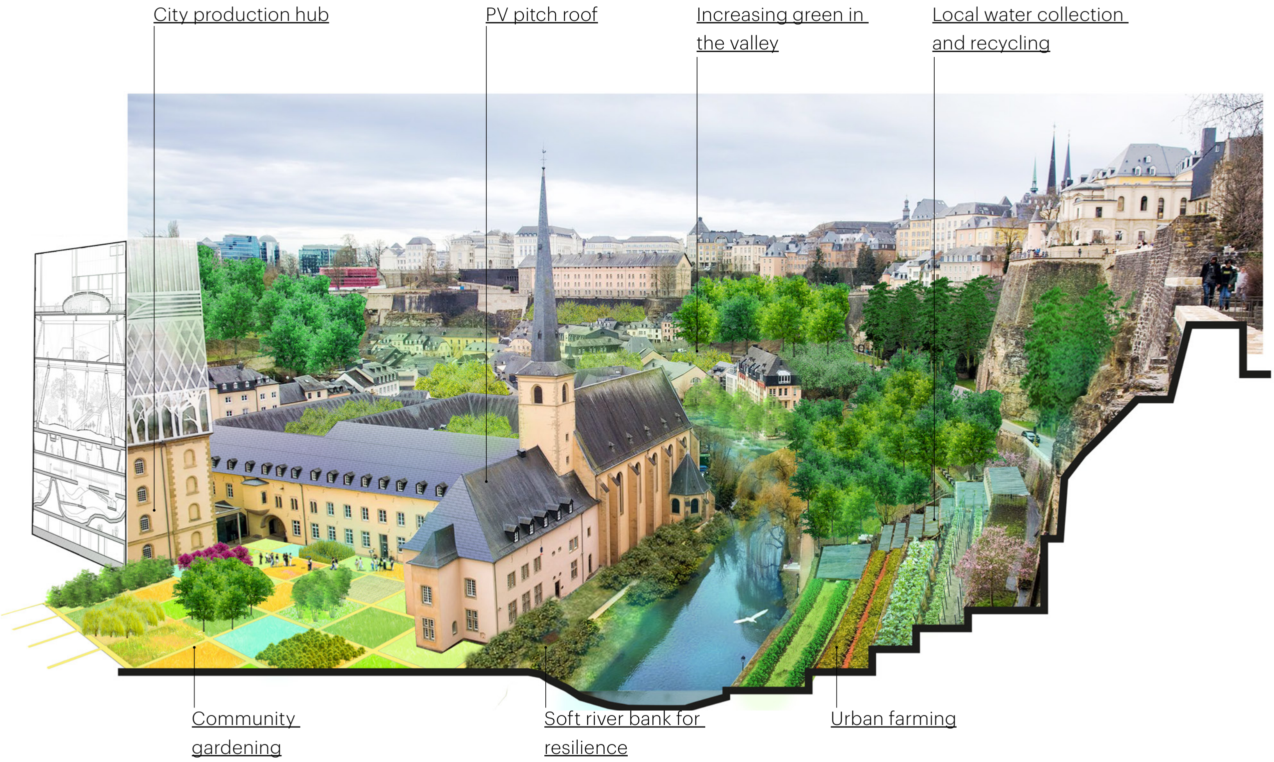
(re)purposing the land



Collage of re-naturalization of land (preliminary study)

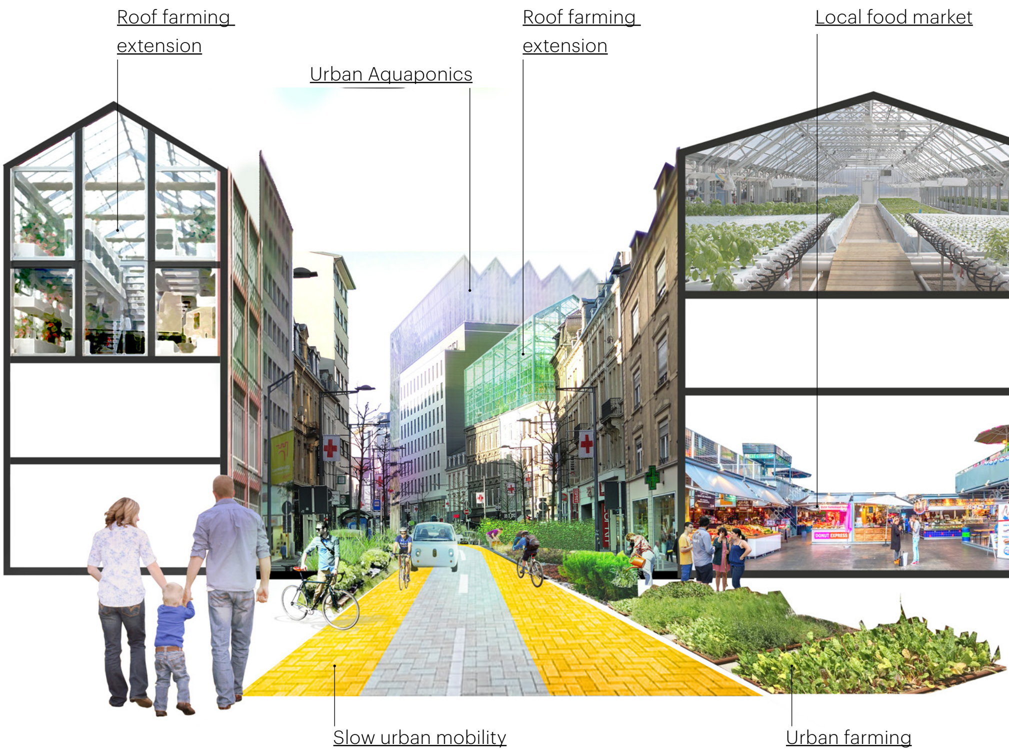
(re)generative Hubs

Catalyzers for healthy lifestyle



Collage Biodivercity - Imaginary on integrated nature and localizing production with consumption (preliminary study)

Contributing to synergies among themes



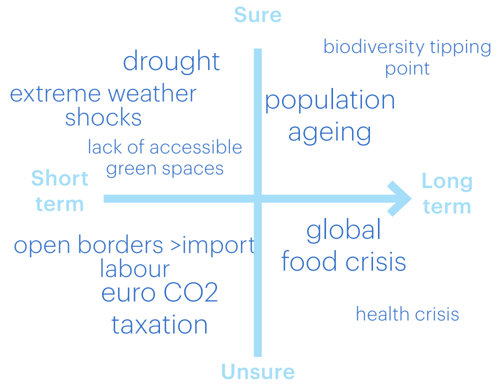
Collage City streets - Imaginary on integrated hubs (preliminary study)

Phasing the bucket list by 2050

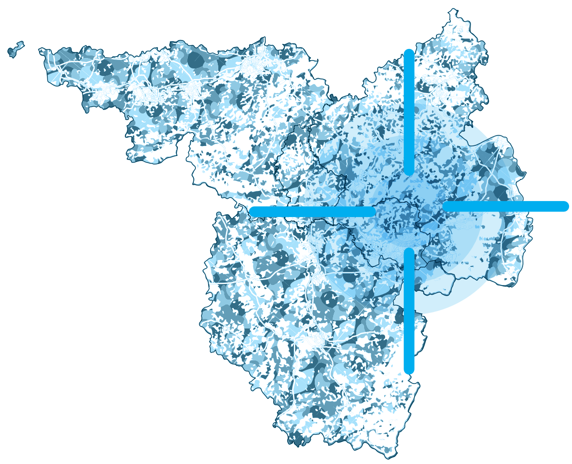
A regenerative approach takes place in time and in space

Prioritisation is crucial in order to apply the right actions at the right time
shocks ans stressts that require an immediate response, such as pandemics or extreme weather events. Other issues will require continuous action beginning in the short term, because they relate to chronic problems that accumulate and persistently impact on both local systems, and global systems. Determining the critical transition needed informs prioritization. This directly correlates to challenges associated with phasing out established regimes that face elimination or change, and to the power behind emerging alternatives and initiatives that enable new sustainable regimes. Prioritising the conversion of actions to solve these difficulties pushes transition forward, as does prioritising small efforts that have a greater spin-off effect in transition.

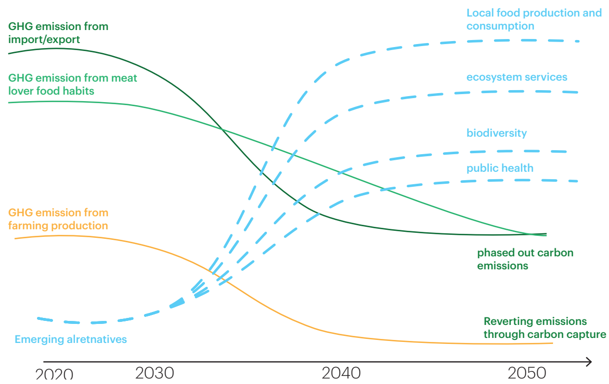
Emergency analysis



Coordinating when and where can make all the difference
Feasibility is important to determining when and where transition will happen. For instance, converting a farm into an organic facility will take 2 or 3 years, but this transition hastens with incentives and technology. However, cultivating a forest or a forestry system takes 10 years, without short cuts. Following the same example, there are areas that are more suitable for cultivating forests, either because of existing conditions, such as soil quality, slope, wind, and water; however, because of the effect procured, such as the cooling impact on urban areas, a systems-based approach would imply in locating forests in peri-urban areas as a preferred solution.



The magnifying effect of regeneration
Quantifying the impact an action must achieve at prescribed milestones is essential to the effectiveness of transition measures. However, we must consider the effects in the context of time. Sometimes a transition measure implies accumulating losses in the short term, but guaranteeing higher gain in the long term. We can mitigate certain losses, but some are simply habits that we must surrender or regimes that must expire, through "negotiations" or "trade-offs". Each action also has positive impacts, that reverberate and join forces one with the other, across themes and scales.



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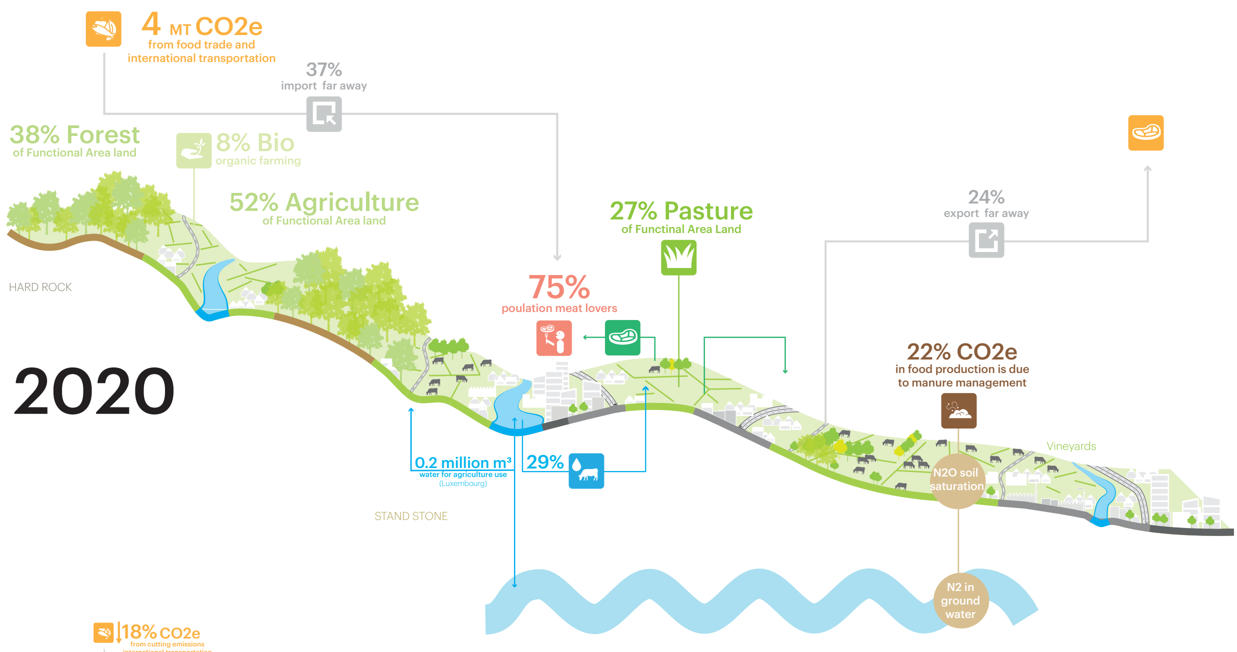
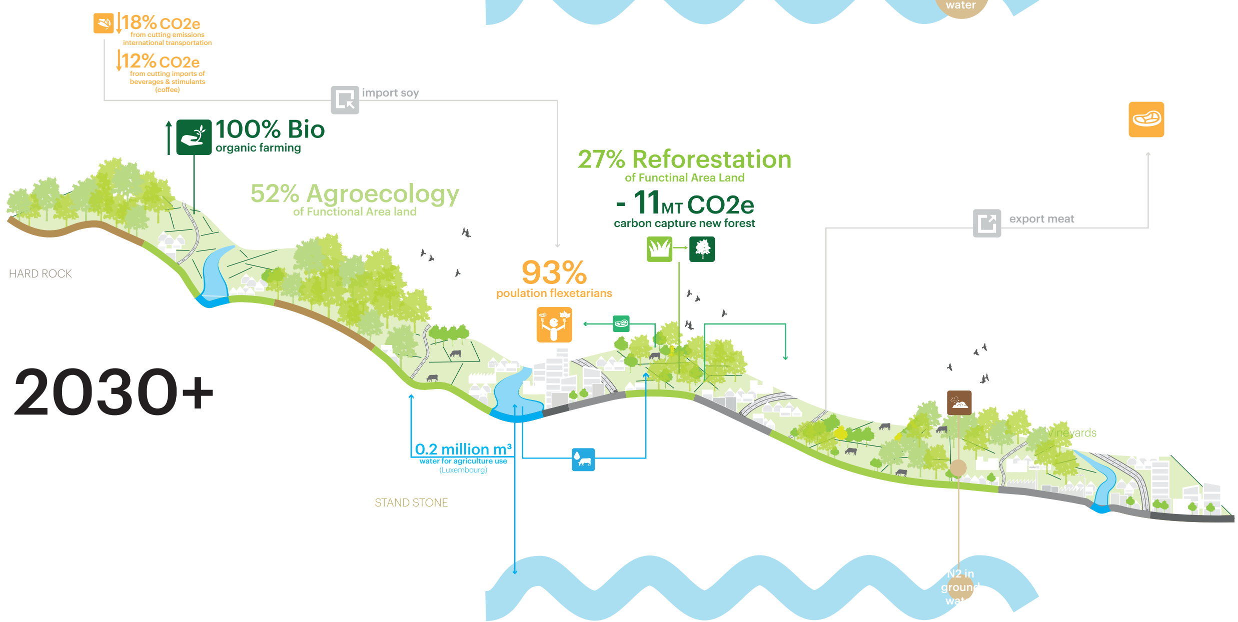
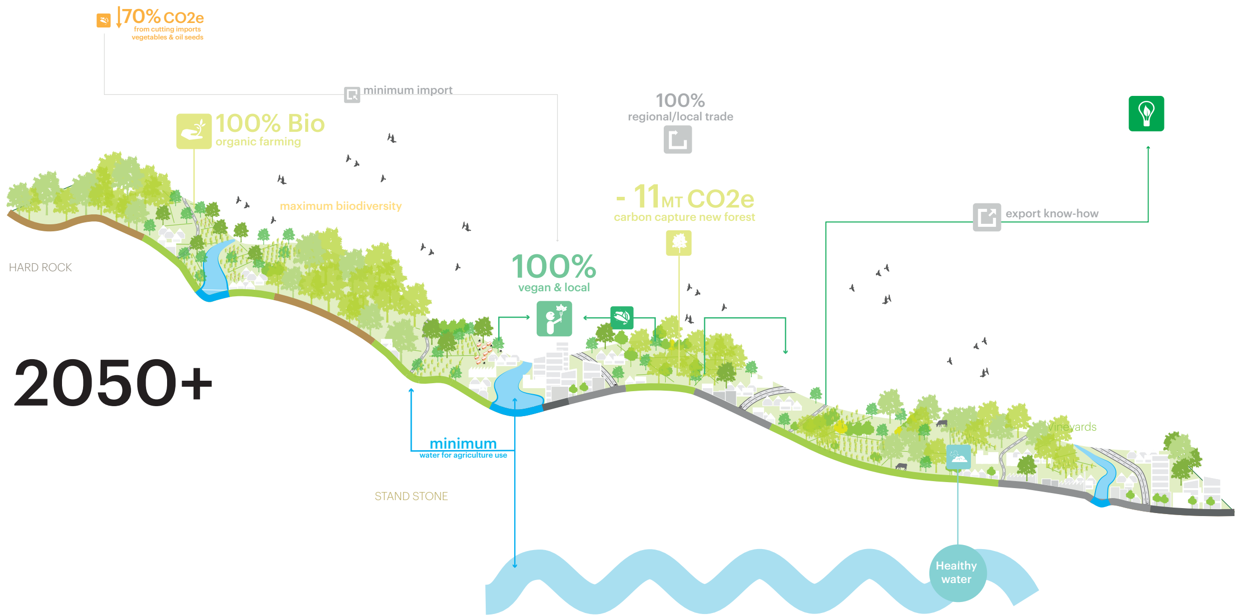
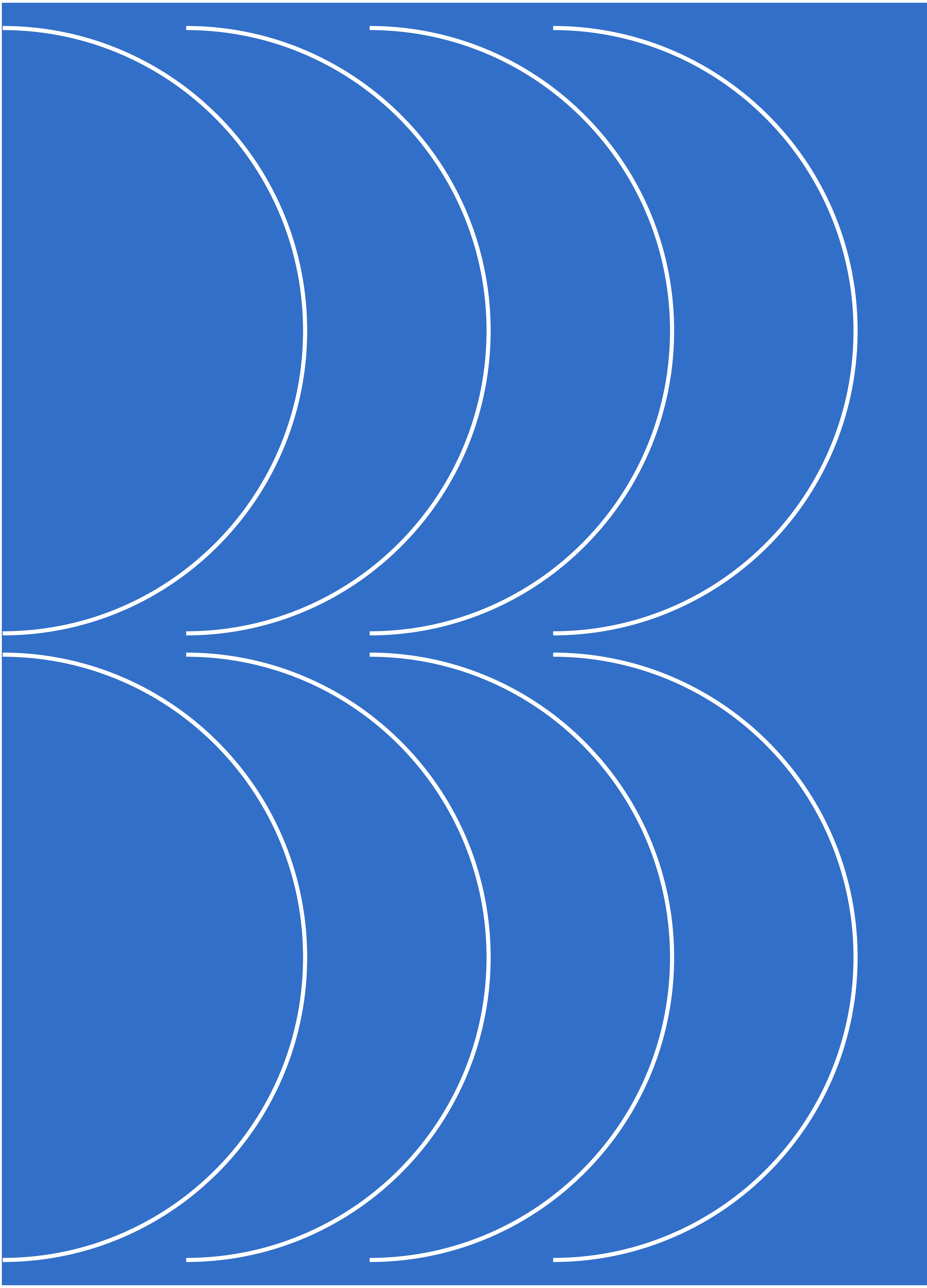


2030+



2050+





Nine steps: design-led methodology

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Methodology Overview

The approach and methodology to achieve targets for Luxemburg propels a shift that surpasses zero carbon targets to achieve comprehensive regenerative transition. To understand the inherent value and impact of this methodology, it is integral to understand it not only in spatial or quantitative outcome terms, but also as a qualitative process. By definition, regeneration moves beyond even circular principles, aiming to generate synergies, and connections to other systems in place to support full integration. Three core principles underpin this methodology:

- Vision: supporting qualitative and spatial configurations
- Tools: operating as interventions, governance tools, or temporal compositions
- Metrics: supporting a series of steps to partially or comprehensively measure regeneration based on existing conditions

These three methods form the nine key components of the methodology, combining both retrospectives and forecasted approaches in order to facilitate multiple transitions. The entire team of experts will support this methodology, leaving it open for integration with other collaborators who provide additional insight on discrete themes.

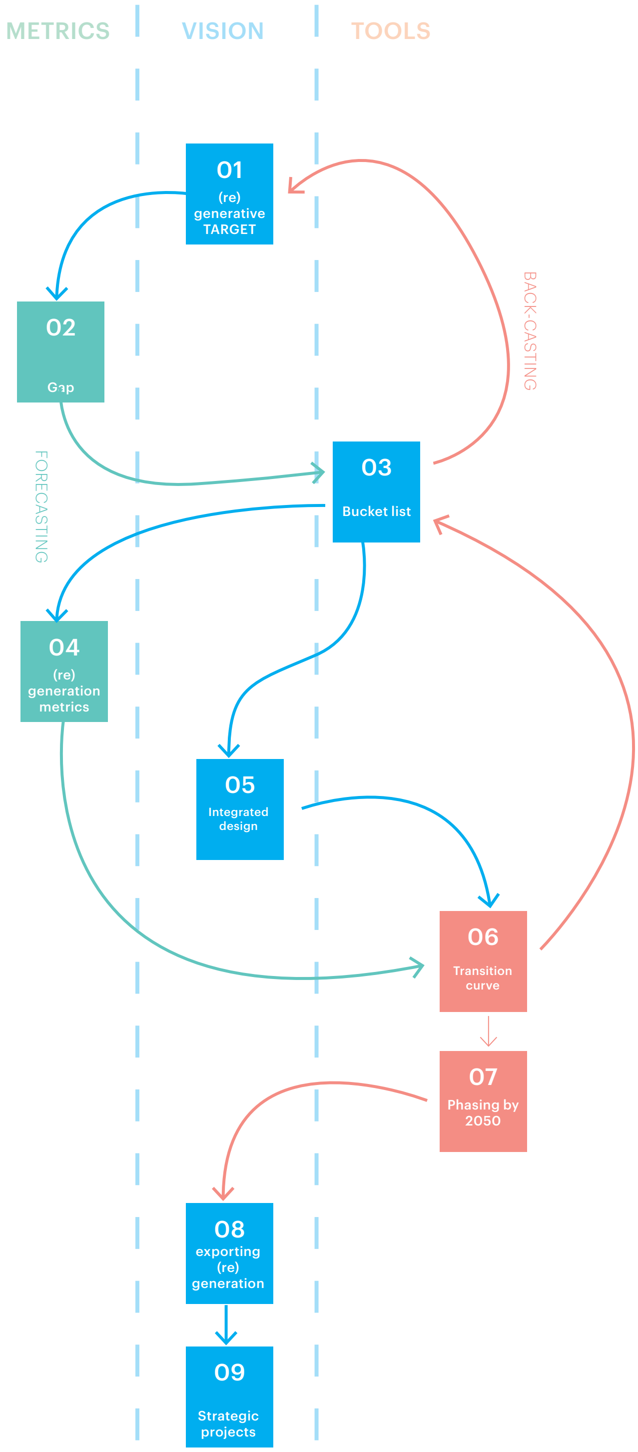
To this end, the methodology supports an adaptable and integrated approach that is designed to enable effective collaboration beyond the scope of this competition to incorporate a broader community of experts, as well as initiatives and activities of related entities. This relies on an understanding that the nature of this transition is iterative.

The change it brings will not come from a linear methodology, but rather a continually developing one.

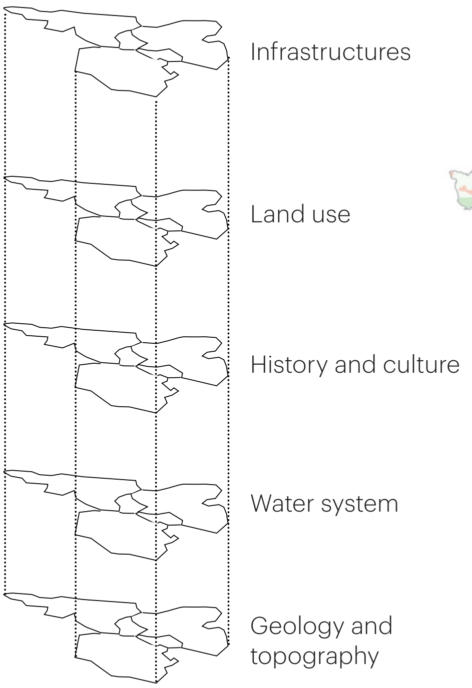
At the completion of Phase 2, societal actors begin to enter the equation. This involves:

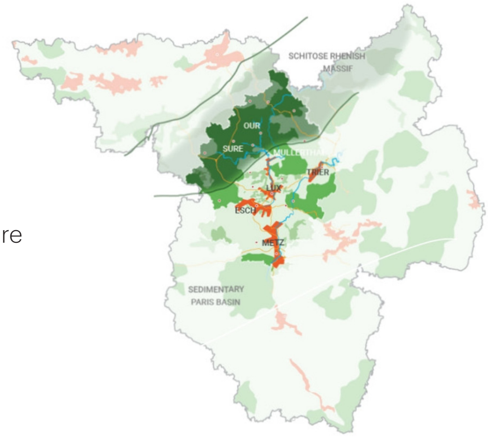
- Participatory visioning with retrospectives, and governance strategies
- Co-production, by empowering local actors to ensure and empower them that they play an integral role in the transition
- Client involvement, to help take on their new role and by gathering knowledge in order to institutionalize emerging resilient, regenerative practices

It is imperative to consider that this methodology is not exclusively a vision or goal, but instead, it is a process. The nine steps outlined bring this process towards a vision with collaboration, adaptability, and systemic rigor as foundational imperatives.



01 Understaning the territory

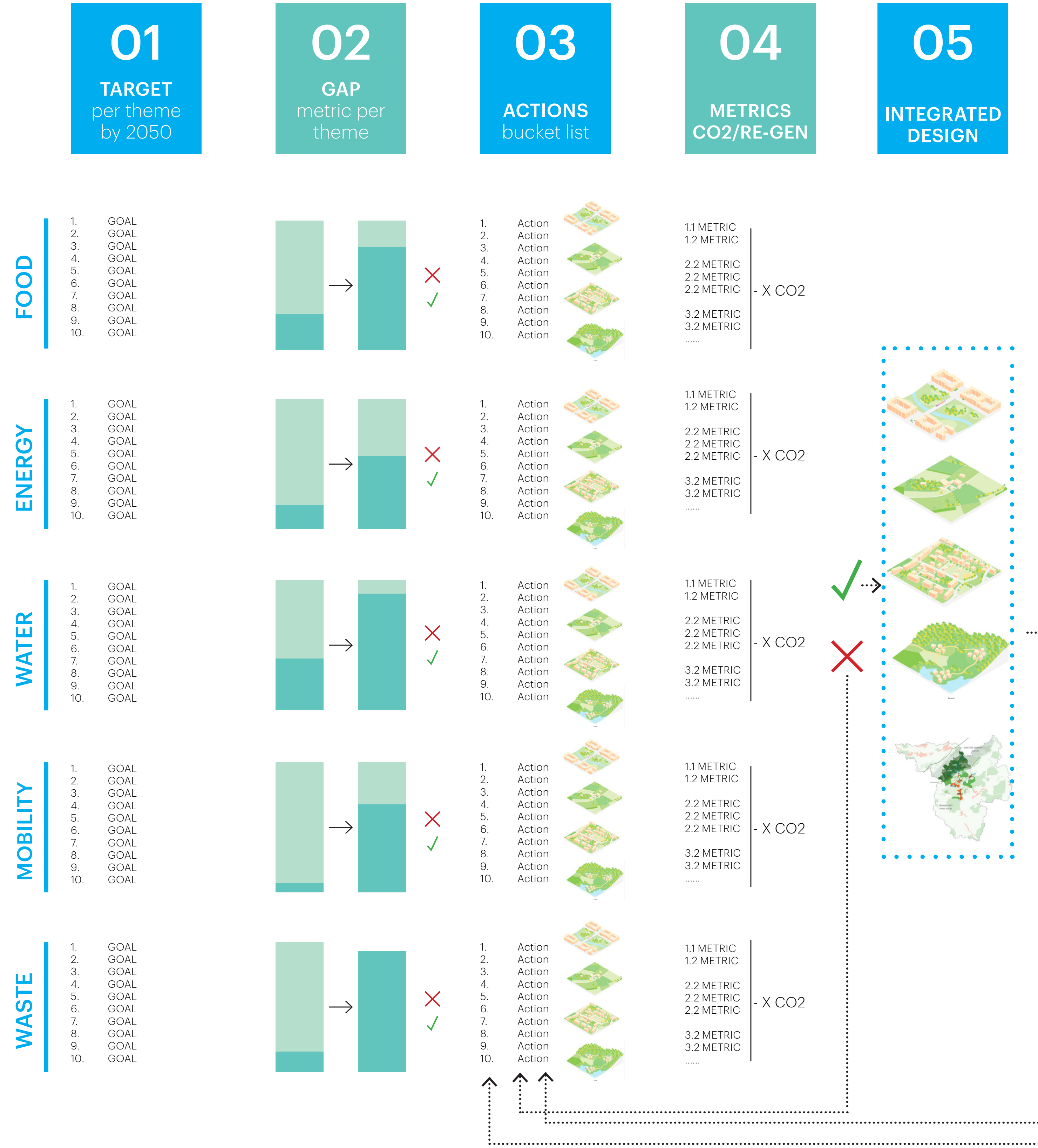




02 Methodology to integrate the systems

- **01** (re) generative target
- **02** Gap
- **03** Bucket list: actions & tools
- **04** (re) generation metrics
- **05** Integrated design
- **06** Transition curve
- **07** Phasing by 2050
- **08** Exporting (re) generation
- **09** Strategic projects

03 Taking in account all existing initiatives



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TARGET
per theme
by 2050
02
GAP
metric per
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03
ACTIONS
bucket list
04
METRICS
CO2/RE-GEN
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INTEGRATED
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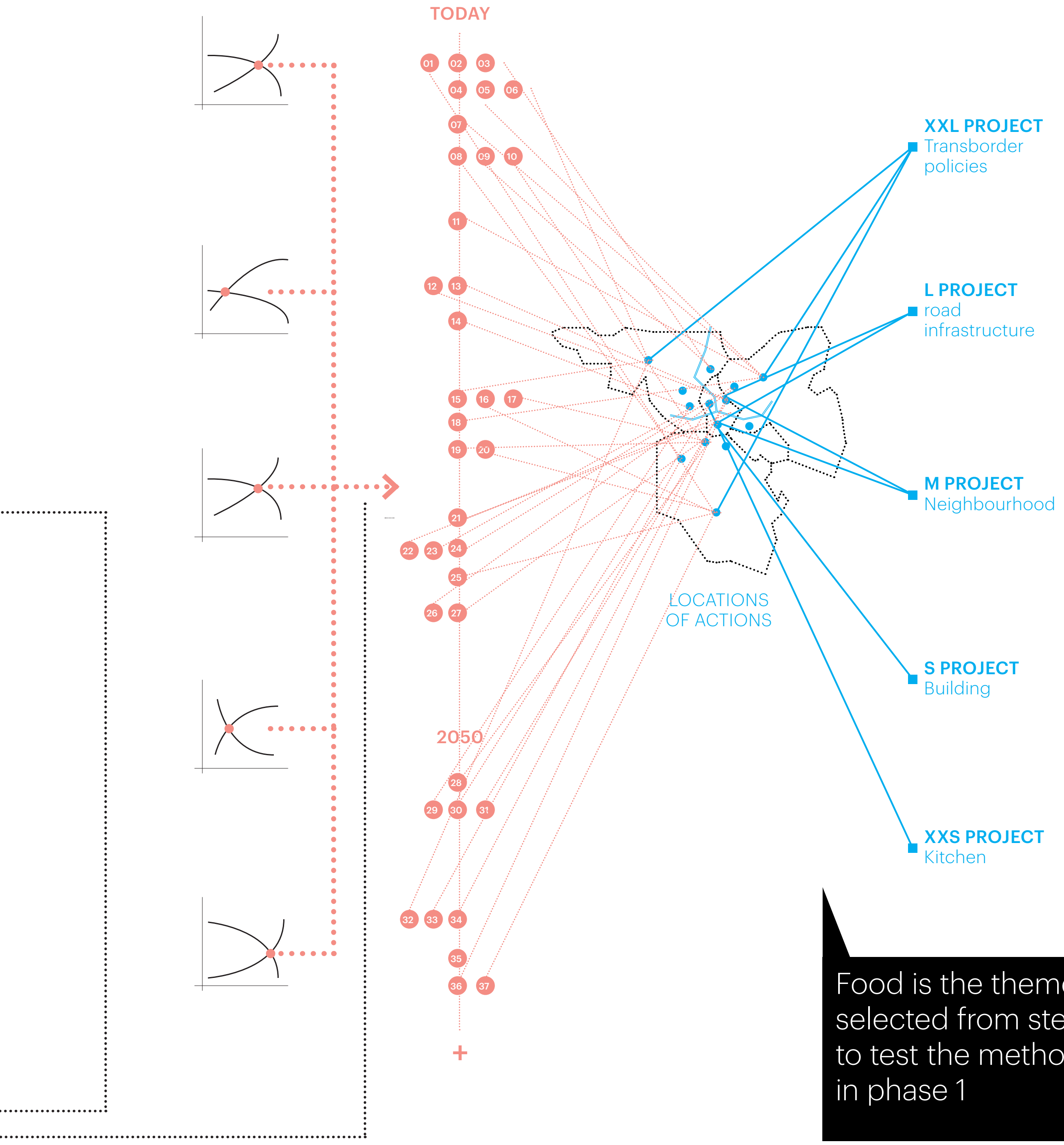
06 TRANSITION CURVE

07 PHASING 2050 graph

08 exporting (re) generation visualization

09 STRATEGIC PROJECTS design

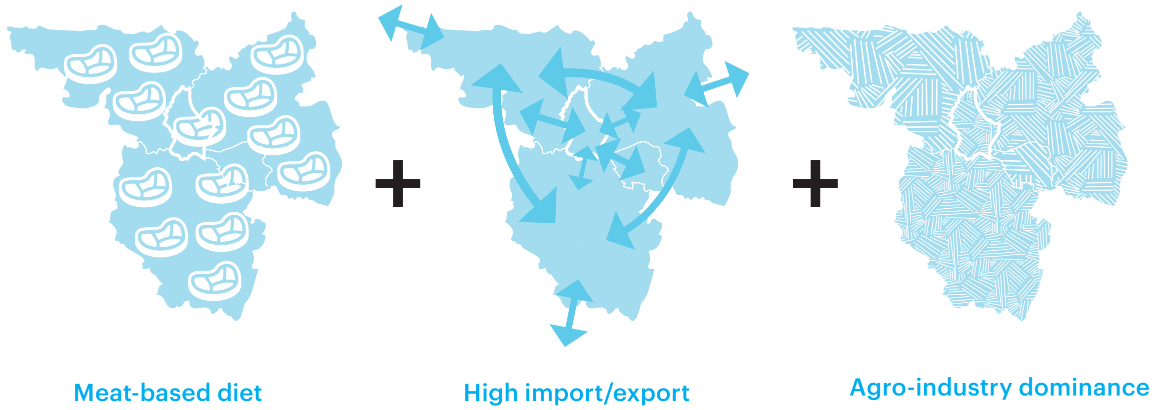


Food is the theme selected from step 1 to 6 to test the methodology in phase 1

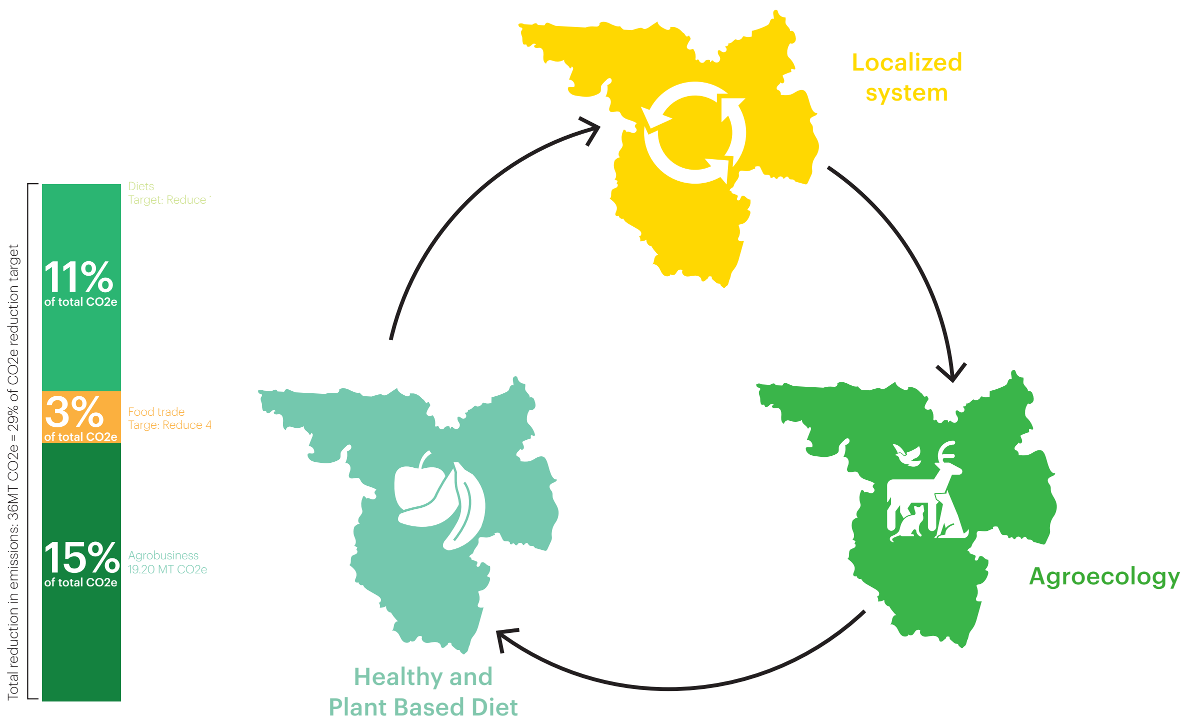
STEP 01: (re)generative target

The explicit target is this: achieving a regenerative system by 2050 that contributes to all planetary systems through the generation and combination of sustainable, and resilient interventions, propeling a shift beyond mainstream zero carbon, circularity, and sustainability initiatives to forge systemic integration.

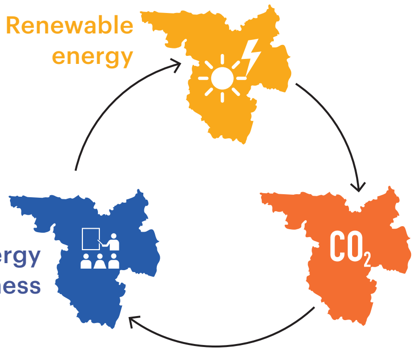
From unsustainable food system...



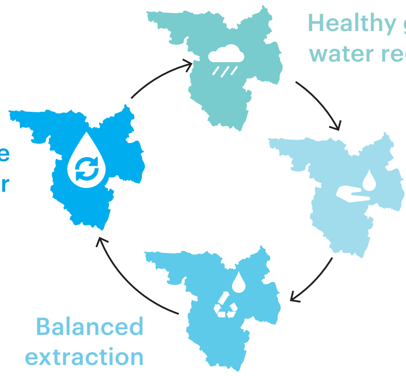
...towards a (re)generative food system



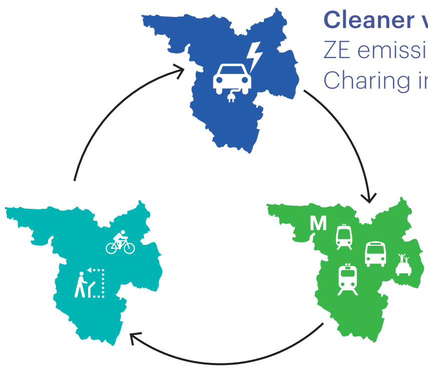
... towards a (re)generative energy system



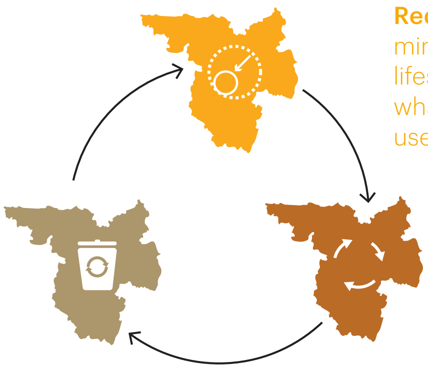
... towards a (re)generative water system



... towards a (re)generative mobility system



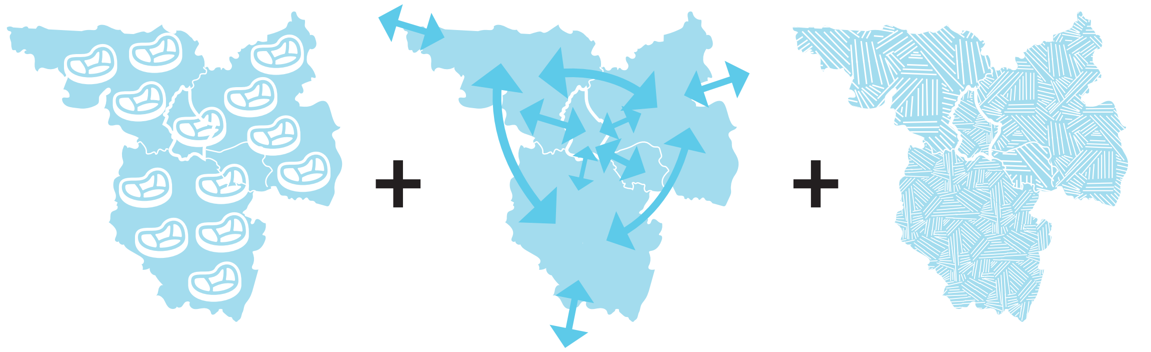
... towards a (re)generative waste system



STEP 02: GAP - what will it take to get there?

This step quantitatively articulates the status quo and then determines the capacity to reach the explicit target. That said, it is not only the number or percentage that defines this status, but also the nature of the initiatives currently underway, or which have been deployed, and how much effort at a process or governance level is required to move toward the explicit target.

Consumer behaviour represents the greatest challenge to the target

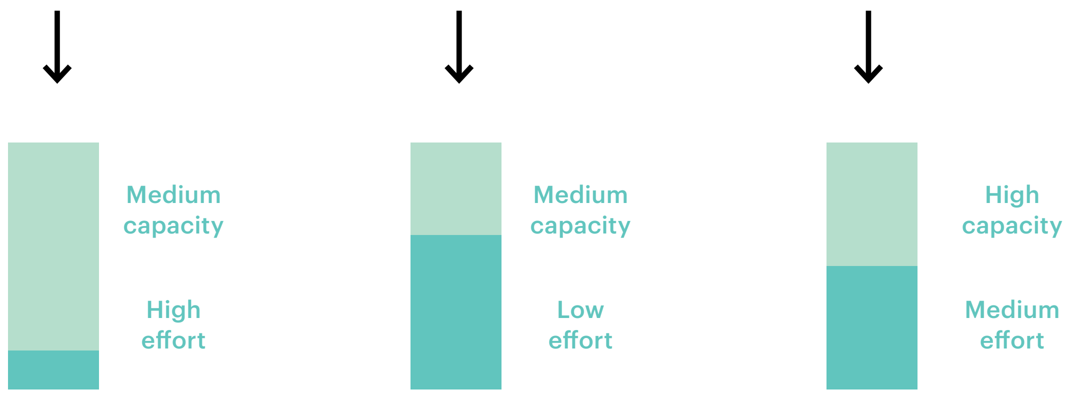


Meat-based diet + High import/export + Agro-industry dominance

75% Population consuming a meat-based diet

37% Of imported food

52% Of agricultural land, of which 51% is pasture



Gap for a (re)generative Energy system

40%
building requalification needed

89%
total no renewable energy production

100%
needed of energy storage system implementation

Gap for a (re)generative Water system

90%
run-off draining quickly

80L
consumption of water per capita per day above the EU average

19%
surface of water-bodies in good condition

Gap for a (re)generative Mobility system

78%
crossborder commuters going to Luxembourg

40%
of GHG emisssions due to transportation

50%
of short car trips on bikeable distance (<7,5km)

Gap for a (re)generative Waste system

30%
reduction in specific disposable waste production by re-use

175%
of EU-28 average of domestic material consumption per person

55%
Recycle target of all housewaste

STEP 03: Bucket list (tools & actions)

Actions taken to achieving the regenerative target include the interventions (both spatial and behavioural) which bridge the distance between the status quo and this achievement. Tools define the nature of the intervention itself.

Step 3

01 TARGET	02 GAP		03 ACTIONS (TILES)			
REGENERATIVE GOAL	GAP (low,high)		03 ACTIONS		Quantifications	Tools
A HEALTHY PLANT- BASED DIET						
		1.1	Nutrition transition to Reduce CO2			
			Change Food Habit to reduce meat consumption	Q1	from 2% vegan population to 100% vegan from 30mt CO2 current habits to 17 Mt CO2e	veganism
			Decrease CO2 by eliminating animal-products	Q2	vegan habits	substitute animal farming with plant-based farming
			Increase forest area	Q3	**70%** increase in forest area	
			Potential CO2 reduction of food transition	Q4	44% reduction in t CO2	add area of forest to capture carbon
Phase out meat-lover habits	**Food consumption habit: Meat Lovers 75% of the population**	1.2	Repurpose land per food habit			
			Reduce land use of pasture and meat production	Q5	from 51% dedicated to pasture to 0%	eliminate pasture land use
			Potential reduction in land requirement by shifting food habits	Q6	from 3x agruculture land (import) to 1/2 of agriculture land	redistribute types of production land
		1.3	Change what is produced locally			
			Rebalance production of plant-based foods	Q7	tonnes produced	agroforestry, urban agriculture, edible garden
			Increase awareness about food chain and waste	Q8	% of population that is aware	proximity to production (visibility), eductaion, media, bonus/onus incentives
			Reinterpret what is edible	Q9	tonnes of alternative foods	eductaion, media, bonus/onus incentives
B LOCALIZED SYSTEM						
		2.1	Optimize production to strengthen local supply			
			Rebalance crop-animal ratio according to local ecosystem	Q1	tonnes of food produced per type	agroforestry
			Produce more in the same space	Q2	yeld per ha	precision agriculture tecnologies
			Reduce water use	Q3	x% less water	smart irrigation, water circularity
			Reduce energy use by creating synergies	Q4	50% less energy	place farms close to highways or industries to use theis energy surplus
			Repupose organic waste with compostage	Q5	% less food waste	place urban edible gardens close to restaurants to use their organic waste
Reduce import/export in 37%	**Imports from far away are 37% of the total**	2.2	Shorten the supply chain			
			Minimize import pressure	Q6	land requirement deficit	ecotaxes on CO2 impact of transport
			Minimize yield production to export	Q7	tonnes export	social taxes for non-essential exporting
			Reduce C02 emmited in food transportation	Q8	tCO2e food transportation	prioritize rail and waterways, and enhance access
			Reduce food waste lost in transportation	Q9	tonnes of food lost in transportation	redistribute landuse and mix farm and city
			Reduce food processing and packaging	Q10	tonnes of processed food	ecotaxes on packaging
			Increase access to local fresh food	Q11	Fresh food market number , frequency and coverage	streets and avenues closed for temporary events
			Maximize urban agriculture	Q12	km2 of urban ag	edible gardens using openspace, rooftop garden
C AGROECOLOGY						
		3.1	Change from agro industry to agro-ecology			
			Maximize reforestation of agriculture land - pasture + cultivated cropland	Q1	food classes/ha	agroforestry
			Maximize perenial crops productivity	Q2		environmentclimate driven design of production spots
			Maximize carbon capture	Q3		prioritize species with high carbon capturing capacity
		3.2	Increase productivity of agroforestry			
			Increase productivity of organic farming	Q4	100% of organic farming	bio-fertilizers, climate design
			Introduce eco-corridors into farmland	Q1	km of eco-hegdes	hedges
			Optimize soil health for fertility	Q2	soil indicators	soil ploughing
50% of agrobusiness to change into agroecologic	**“foodprint” of agrobusiness due to 51% agriland for pasture and cows**	3.2	Eliminate fossil fuel and artificial fertilizers			
			Use green energy machines	Q7	expenditure in e-trucks	provide electric machinery charging spots
			Increase poeple-based farming	Q8	worforce in agro	techical and high education in farming
						proximity to organic waste makers (industry and restaurants)
			Decrease use of artificial fertilizers	Q9	tonnes of fertilizer	
			Reduce CO2e from fertilizer production	Q10	tonnes or % of crops that use it	
		3.4	Relief urbanization pressure on productive landscapes			
			Fix the urban fabric perimeter	Q11	km2 of urbanized area	planning policies
			Accomodate population growth within existing urban areas - densify and redistribute centralities	Q12	People per sqm	densification, infill, adaptive reuse, mixed landuse

Food test: actions + tools + scales *(full table in Annex)*

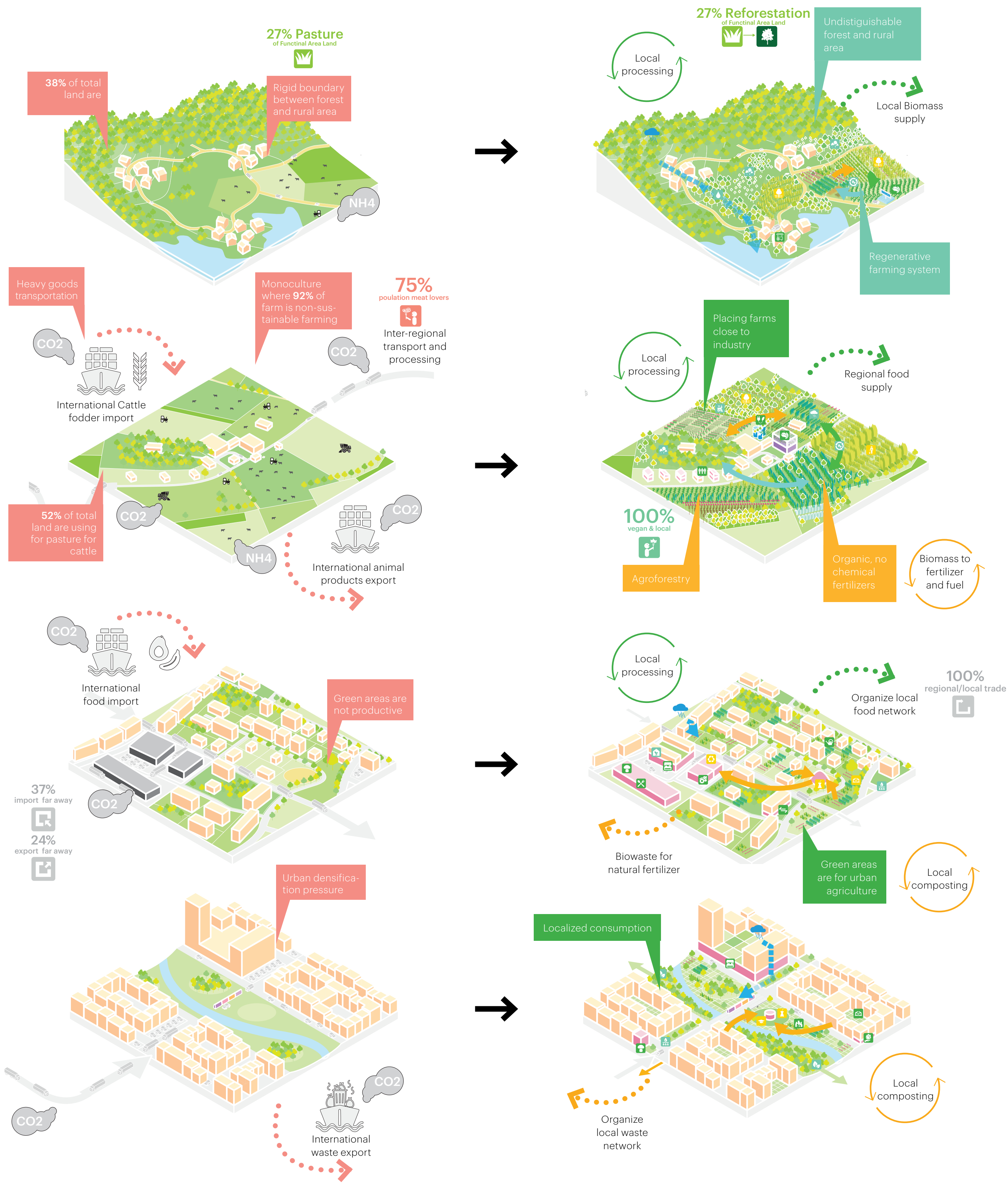
Based on the three regenerative targets, we prescribe a series of actions outlined in this table. Once we reduce these to quantifications and combine these actions with tools in a multiscale approach, we then measure potential positive and negative impact.

Step 4 | Step 6 | Step 7

	04 METRICS							05 INTEGRAT	06 GOVERNA	07 PHASING (SECTIONS)		
Scale	Positive outcome				Negative outcome			Mitigation (T	Priority	2030	2040	2050
										Cumulative milestones		
region rural region rural rural rural + urban behaviour behaviour	**Reduce 10% of total C02 emissions of the Functional Area** 44% CO2 reduction in foodprint, from changing to vegan habits	Reduce 64% of the land demanded to supply non-plant based food habits (possibility of phasing out importing and expoting)	Repurpose 51% of agriculture land to sustaibable uses (enhanncing water permeability , microclimate, biodiversity)	30% decrease of N2 in ground water from livestock effluents (enhancing water quality and biodiversity)	20% economic loss from meat processing and preservation	95% of the population will need to change food habits	"Transfering" the meat and dairy products to importation, creating a bigger footprint	Growth of Fruit and Vegetable industry Develop alternative Policies to avoid "transfering" the problem Redirecting budget to upgrading	75% meat lovers 18% flexetarians 2%Vegetarian Largest populatioı Rhineland and Wa Lorraine Saarland Luxembourg	Rededicate land and production, change supply, incentivise Meat lovers turn flexetarian = 66% of "chnaging food habits" Target achieved	Public sector facilities (schools, hospitals, etc) provision of vegetarian meals only MeatLovers + Flexetarian turn vegetarian = 82% "chnaging food habits" Target achieved	(Heavy taxation in carbon heavy foods, especially meat & dairy products) Meat lovers + flexetarian + vegetarian turn vegan = (100% of "chnaging food habits" Target achieved (-44% CO2 emissions)
rural+peri+urban periurban urban	**Reduce 3% of total C02 emissions of the Functional Area** 33% CO2 reduction in the emissions related to international transportation and trade	Reduce dependency on 37% of imports coming from far away (Resilience to "lock-down" stresses like COVID 19)	Reduce burden of 24% of exports going to far away destinations	Reduce food waste in transportation Increase nuritiion factor and enhance public health	37% economic loss from import	24% economic loss from export	Access to Diverse foods, available year round	Invest in local productivity technologies Change to seasonal and conscient food consumption Export knowledge and technology	37%imports comiı 24%exports comiı	Intl food transportation only thorugh electric vehicles and clean modes = 18% of "food trade emission" reduction target achieved)	Cut imports of beverages and stimulants (coffee) = 30% of "food trade emissions" reduction target achieved	Cut imports of vegetable & oil seeds (soy) = 100% of "food trade emission" reduction achieved
natural + rural rural + perirban rurual+ periurban region region rural rural region urban urban	**Reduce total of 15% of total CO2 emissions of the Functional Area** Reduce 2 MT CO2e emission from chemical fertilizers Reduce17 MTCO2e emissions by capturing carbon with reforestation	Not emmit 6% of CO2 from pasture/animal farming land use Dedicate 17390km2 of pasture to forest or afroforest in periurban areas	Increase Water quality by reducing 50% of N2 in groundwater from chemical fertiliezers (increase ater quality, biodiversity, reduce eutrophication risk)	Temperature decrease of 3°C in urban centers with reforestation in periurban areas	Long time wait for afforestation	Productivity of organic farming and agroforestry sustems is lower in comparison to intensive agriculture	Change from machine intensive, large farms to human-intensive smaller farms would also impact economy and employment relationships	Invest in agroforestry productivity technologies Incentivize a stronger job market arund organic farming and other sustainable parctices	Chemical Fertilize Pasture land-use	Cut down the use of chemical fertilizers and support (subsidies, tax abonemnent) sustainable agriculture practices = 11% of 'agroecology target"	Convert an area of 17390 km2 that today is dedicated to pasture, into forest = 58% of "agroecology target"	Convert arable land into agroecology stetem= 100% of agroecology target

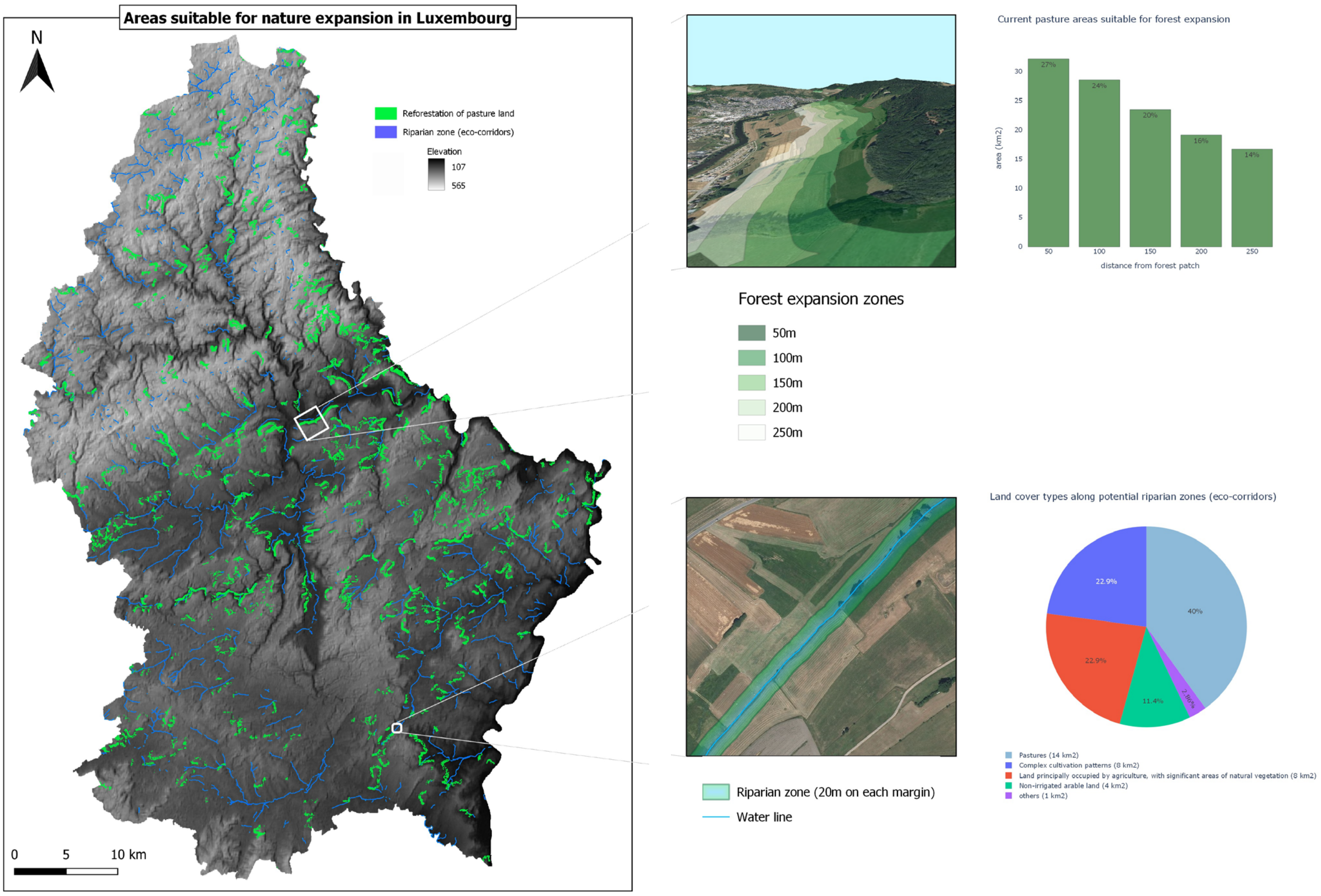
Extraction of actions + tools bucket list from Food test (preliminary study - detailed in excel and annex)

Actions towards a (re)generative Food system



Mapping opportunities: technological support *(more Annex)*

For each theme (food, water, energy, mobility, waste) we develop opportunity maps for each target to help visualise suitable locations and spaces for the implementation of actions to support integrated design. These maps articulate specified suitability criteria and spatial constraints and include priority areas to support a phased implementation. Total area of opportunities for each target can quantify indicators and metrics for spatial actions.

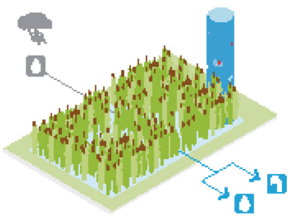


Test to automatize mapping opportunities areas for actions in the food system (preliminary study)

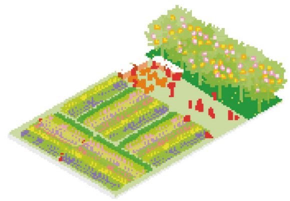
The opportunities map (cross ref.) illustrates the area suitable for nature expansion and reforestation (goal 3.3). The mapping includes the area within a 20 m buffer zone around rivers and creeks (riparian zone), that is currently used for agricultural production (pasture, cultivation, etc.; see clipping lower right). In the Luxemburg territory, around 35 square km of agricultural land can be used for agroforestry or reforestation within this zone.

The second map illustrates opportunities for reforestation in current pasture land of nmpre then 5% slope (see clipping upper right). Opportunities are classified in 50 m steps between 50 and 250 m. Depending on the width of the buffer zones between 26 and 100 square km of pasture land can be redeployed for reforestation.

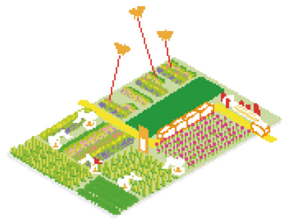
Toolbox for food system actions



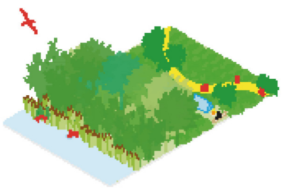
Circularity



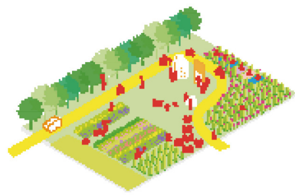
Allotment garden



Agritech

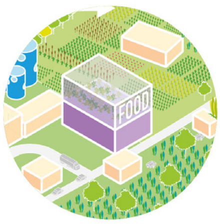


Nature agroforest

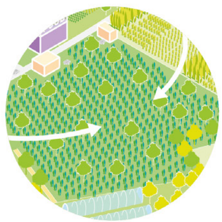


Periurban markets

Water distribution



Local production hub



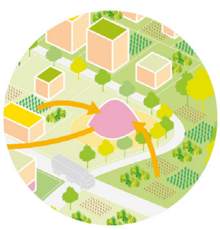
Agroforestry farming

Biogas Energy

Logistic hub transformation

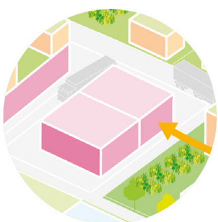
(re)generative Forest

Polyculture



Biowaste depot

Community farm



Waste compost

Education centre

Biodiversity link

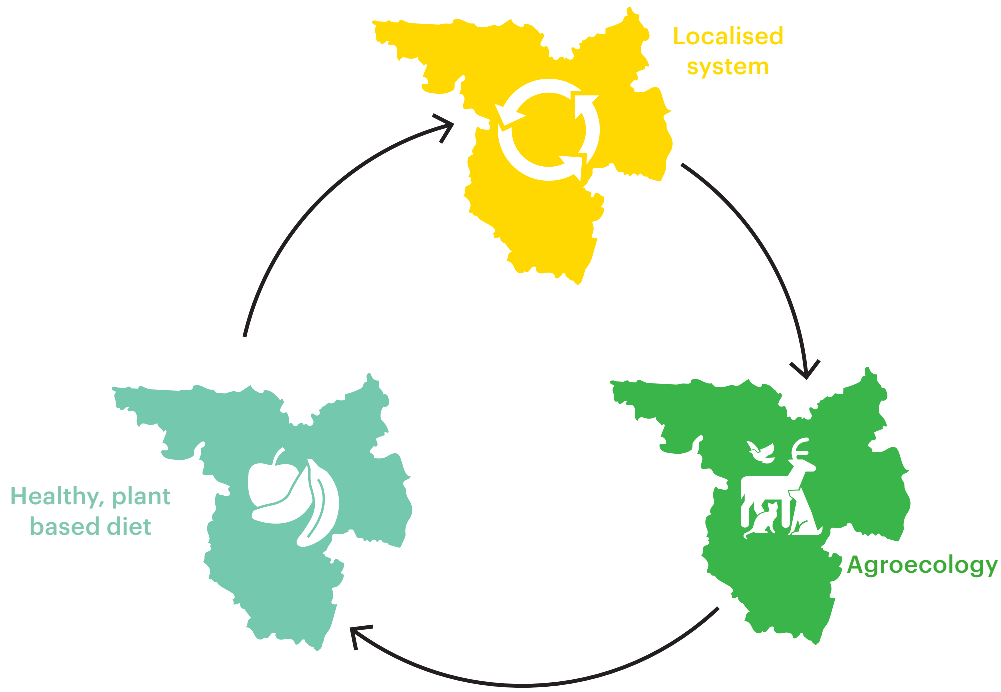
Urban agroecology garden

Toolbox to mitigate negative side effects and to contribute to positive side effects of actions (preliminary study)

STEP 04: (re)generation metrics

Each target within a theme will include several metrics. The metric per target will comprise the consolidation of the positive and negative impact of the actions. These will be quantified, so in the next steps of the methodology, we can propose design solutions for the mitigation of the negative impact of each action.

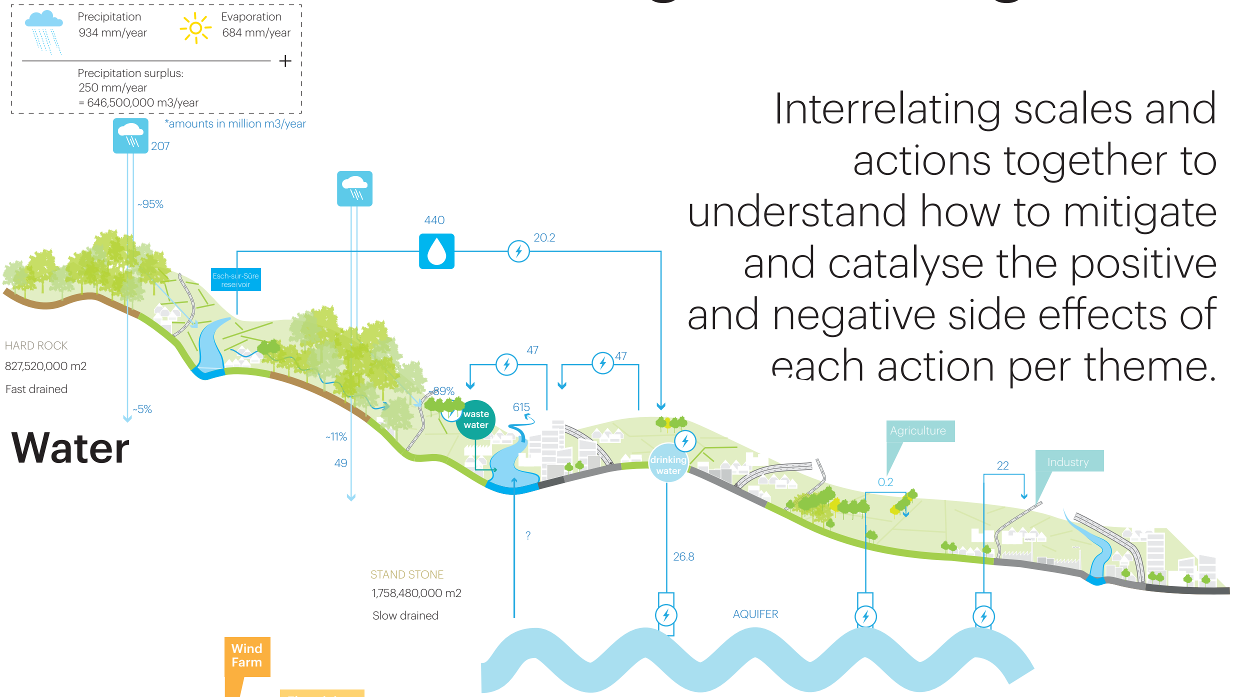
52% CO_2 reduction ensuring (re)generation

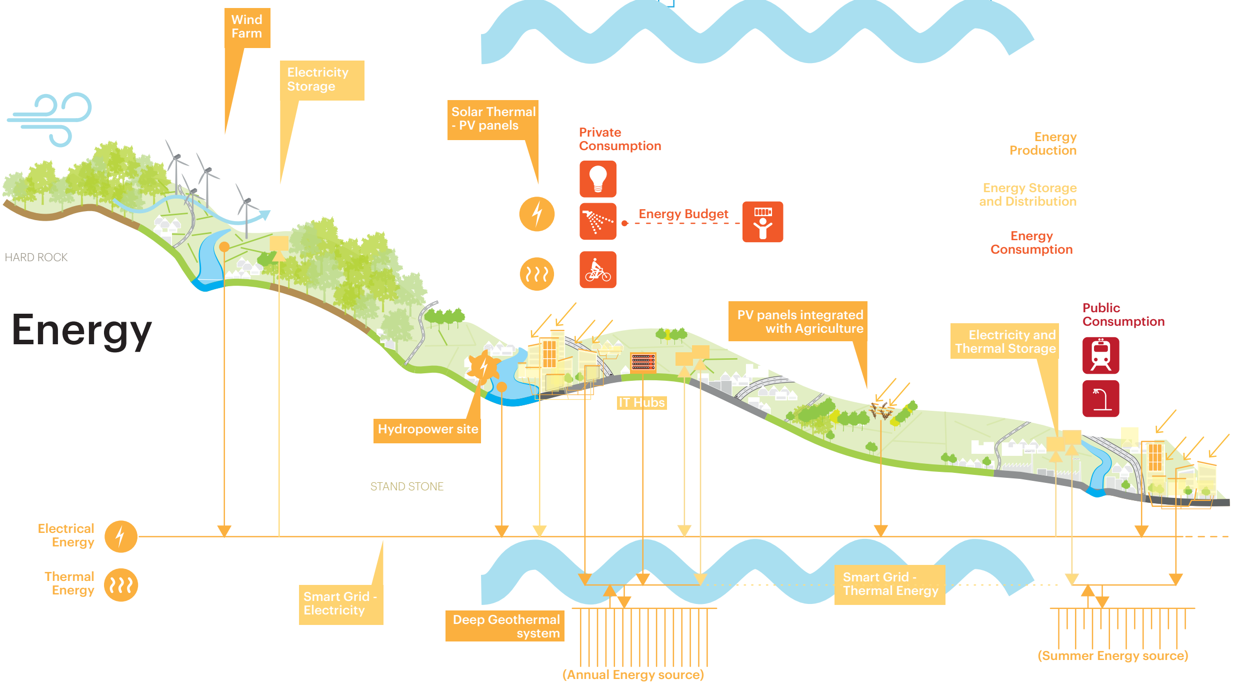


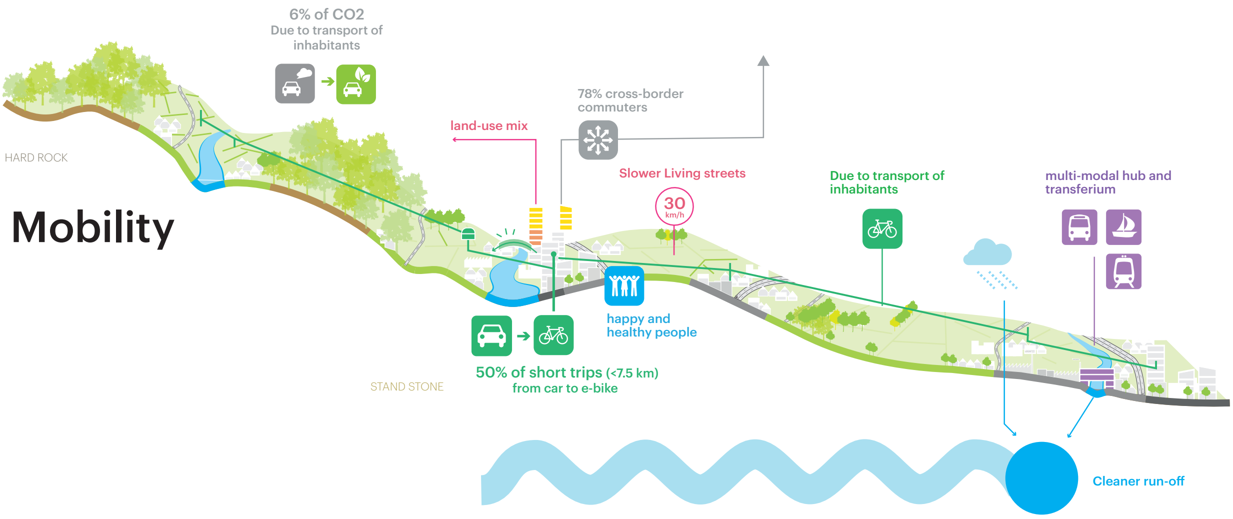
10% CO2 reduction of total emissions	+	3% CO2 reduction of total emissions	+	15% CO2 reduction of total emissions	
64%	land reduction meat based diet production	33%	reduction in CO2 in food production	27%	territory land for reforestation & biodiversity rebuild
28%	of territory land repurpused to other uses	37%	reduction in imports from cutting far away	92%	change to sustainable farming practices
30%	less N2 in ground water from livestock effluents	24%	reduction in exports from cutting far away	50%	decrease on N2 in ground water

STEP 05: Integrated design

Interrelating scales and actions together to understand how to mitigate and catalyse the positive and negative side effects of each action per theme.

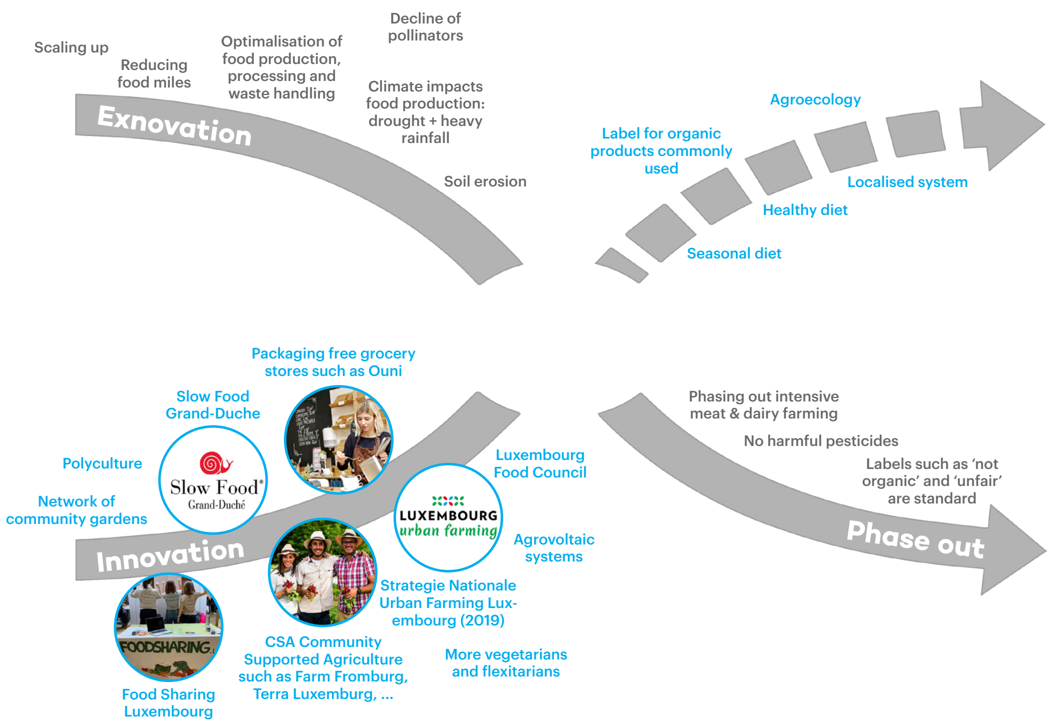






STEP 06: transition curve

Integrated in the implementation of this methodology is determining which initiatives we can phase out, and which we will need to nurture in the long term. Once we have defined all actions required, as well as their level of effort, we use these to inform the toolbox of actions to deploy, and evaluate whether this is a feasible, as well as a healthy process.



Transition curve example for Food system (preliminary case)

Plotting the current transition dynamics of the food system on the x curve, helps us to identify processes already underway in Luxemburg and react and built upon these with our actions and tools.

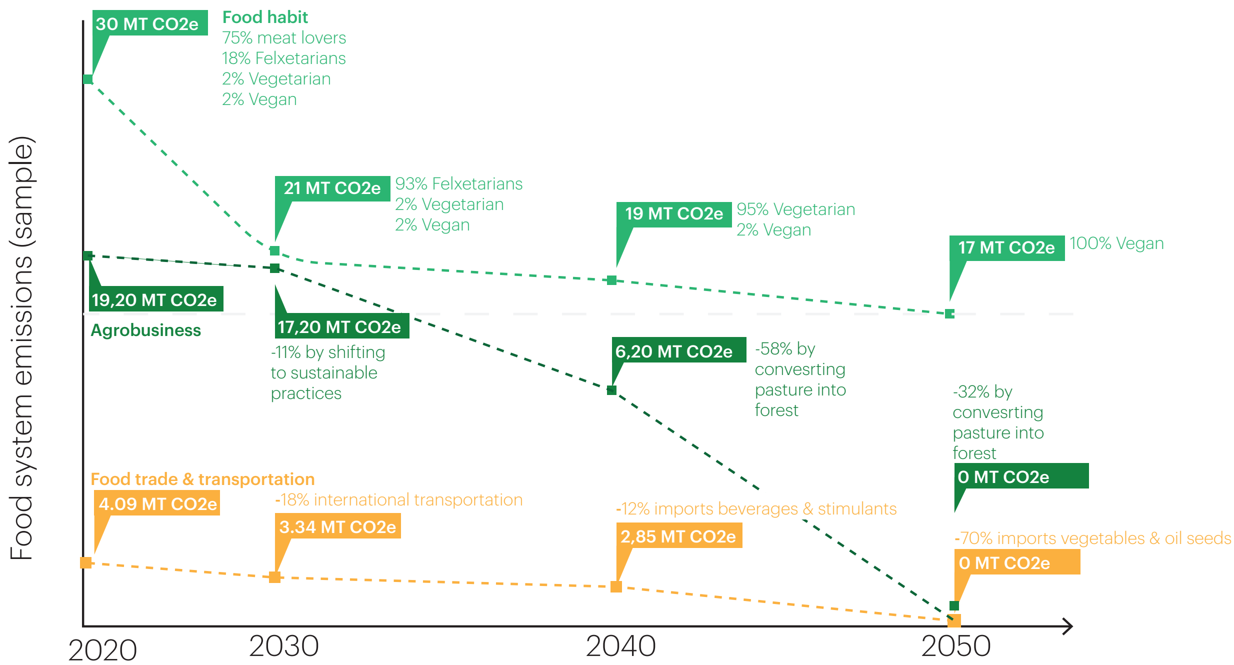
The upward curve represents "innovation" as a process of emergence and building up. Here we see ongoing experiments as well as alternatives that are scaling up. These include the Slow Food movement, networks of community gardens and the government's urban farming strategy. We can also learn from their experiments and look at how to institutionalise their emerging regenerative practices and discourses into novel structures. Taking this forward, it is important to design a process that supports these practices, that resonates with the future vision, for these to become the norm, and to activate and mobilise more and more people to work along these regenerative principles.

The downward curve in the illustration represents a process of breaking down and phasing out: what do we need to let go of to reach a regenerative system? Which lock-ins and optimisations are hindering us? Consider the problems or lock-ins that optimisations such as the scaling up of farms or large monocultures cause. Also, the impact that the climate crisis has on food production is part of this downward curve. We need to consider what we need to redistribute and phase out of the status quo and what exit strategies must be set in place for those whose livelihoods will suffer.

STEP 07: phasing by 2050

When iterative deployment processes have been undertaken, we will have a clear understanding of necessary actions, the consequences these actions will have, and how and when they can be implemented. In essence, phasing concerns timeliness of actions, and making reality the dream. This involves making every action in the prescribed territory over a clear chronological strategy leading us to achievement of milestones by 2030, 2040, and the goal by 2050.

Looking beyond 2050, the total intervention will be enhancing planetary health, and becoming a precedent model of regenerative and resilient transition.



Phasing a Regenerative food system
The three elements of the regenerative food system are composed by aspects that can be placed in time, according to the urgency, the effort it would cost to implement, as well as the reiterative effect one action has in the other.

The overall ambition of this poject targets achieving zero carbon emissions by 2050 (plus a reslience future) beyond that), and we see this as a joint effort, that sum the contribution on mutiple themes (food, watr, eneygy, mobility, waste) towards a cummulative reduction. Within the theme of food, we have analysed three topics in time, that together sum 29% of CO2e reduction in the total emissions of the Functional Area*.

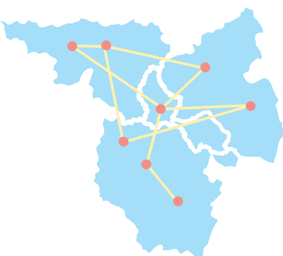
Knowing how much each of these topics can contribute to the CO2 reduction, we set milestones in time, according to urgency and feasibility.

STEP 08: exporting (re)generation

Once all the iterations are complete, we assess the cohort of actions and tools and measure their positive impact. By implementing integral design and mitigating negative impact, we ascertain an understanding of the effort of the transition per theme, and phased the actions in time. The vision then becomes an exportable recipe which can be augmented for different world contexts, and become a precedent reference.

STEP 09: strategic projects

Strategic projects support a holistic, design-led approach to display the ideas, actions, and tools defined in our vision. These strategic projects adhere to a shared understanding of where and what should be integrated in space. The network and the hubs are the key spatial frameworks can integrate with the actions and tools in a coordinated manner.



(re)generative
hubs + network

Visualizations and showcase of potential strategic projects (preliminary study)

What is next?

Lessons learnt

Phase 2 & Phase 3

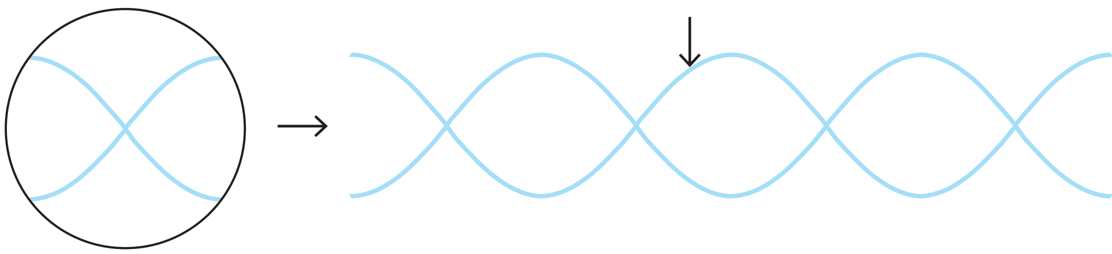
4

LESSONS LEARNED

Our innovative process methodology was co-produced through intense collaborations as a consortium to understand the challenges of the Luxembourg region from a shared transitions perspective. This also required that we reconsidered our own roles as consultants/experts in transition. Hereby our lessons learned:

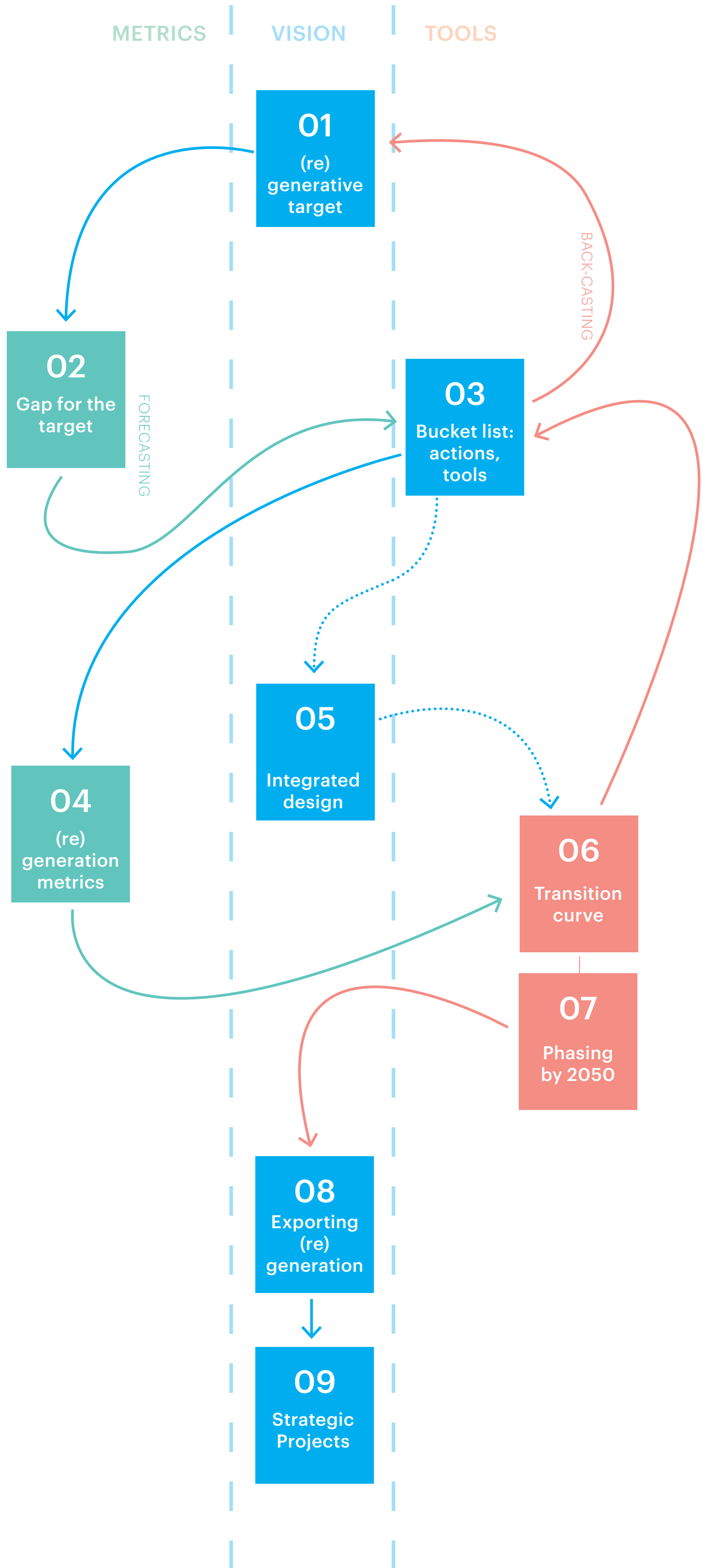
- Transitions cannot be managed, nor guided by experts alone, it builds upon local knowledge and co-production with local actors.
- Facing transitions demands to align first how we understand transitions and what ideology as a consortium we have behind our methodology
- A spatial and landscape approach benefits from a theoretical transition framework to contextualize spatial processes from a societal systems perspective
- Merging back-casting approaches with forecasting (design scenario building) demands intensity on testing and visualizing in order to communicate iterative process
- Testing one theme on isolated matters is challenging since it demands to understand the relationships
- The hybridation of qualitative and quantitative approach is key to be able to understand complexities of transition dynamics
- The methodology demands to be flexible and based on iterative loops in order to give room for spatial innovation together with quantitative rigurosity
- Many things need to be redefine once the first round of all themes is done, then the spatial vision, and the phasing will be accurate enough to understand the design of the process (to be shared with local actors)
- The only way to ensure resilience and sustainability is through thinking out of the box, beyond zero carbon and based on local initiatives
- These initiatives are often designed around other objectives then carbon reduction like: clean air, safe streets, healthy diets, etc.
- Zero carbon becomes one of the means towards resilience and sustainable systems
- This broader scope integrates emerging initiatives, structures and cultures that are already active in the process

Continuity as better, cleaner, stronger future



PHASE 2

- Will focus on laying out the iterative process, per system (energy, water, food, mobility, waste), defining actions, tools, metrics, integrating design, mitigation negative side effects, and combining all them together in time.
- Will start engaging local actors that are working on the transitions already at different structural levels (frontrunners insight Ministry, NGO's, regions, municipalities, local initiatives).
- Will continue defining the transition and resulting in a clear picture what to do first in the local pilots.



PHASE 3

- It is when we will combine our package of actions, in time, and we will allocate them together with a spatial narrative.
- Local actors will be empowered to take their role in the transitions and in governing this innovative process.
- Hubs and network come in place to understand how the vision by 2050 becomes an exportable solution to the planet.
- The strategic local pilot projects support on the showcasing of those design strategies towards providing the right solutions

Colophon

Bidding Team

Consultant
Researchers/advisors transition governance

Main Contractor
Urban + Spatial Planning

Consultant
Landscape design

Sub-Consultant
Sustainability

Sub-Consultant
Mobility & Infrastructure

Sub Consultant
Water Management

Sub-Consultant
Geo-mapping/Spatial analysis

MVRDV
MVRDV

Principal in charge
Winy Maas

Director
Enno Zuidema

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The Annex

This document is meant to provide further detail about the various themes explored in the main document, and compiles the work and contribution from the experts that compose our team.

It also records the process of research and knowledge building to support the proposal presented in the main document.

Main Report **Annex**

Beyond Lux(e)! ANNEX

The study area characterization

1

Thematic Metrics

2

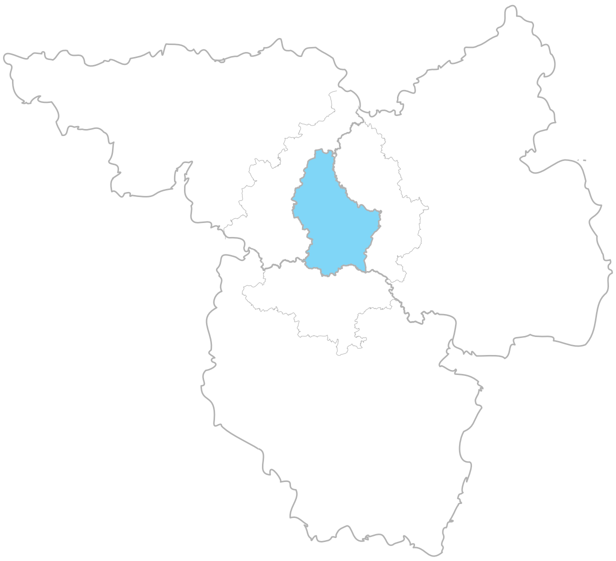
The Study Area Characterization

1

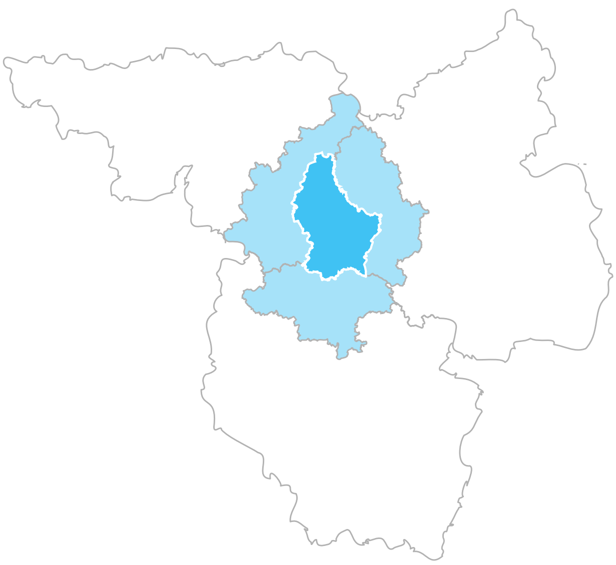
Defining the study area

Having the brief of this challenge defined that the work here developed should encompass beyond the national borders of Luxembourg, its Functional Area, the team came across the necessity of defining the study area for the explorations detailed in this annex.

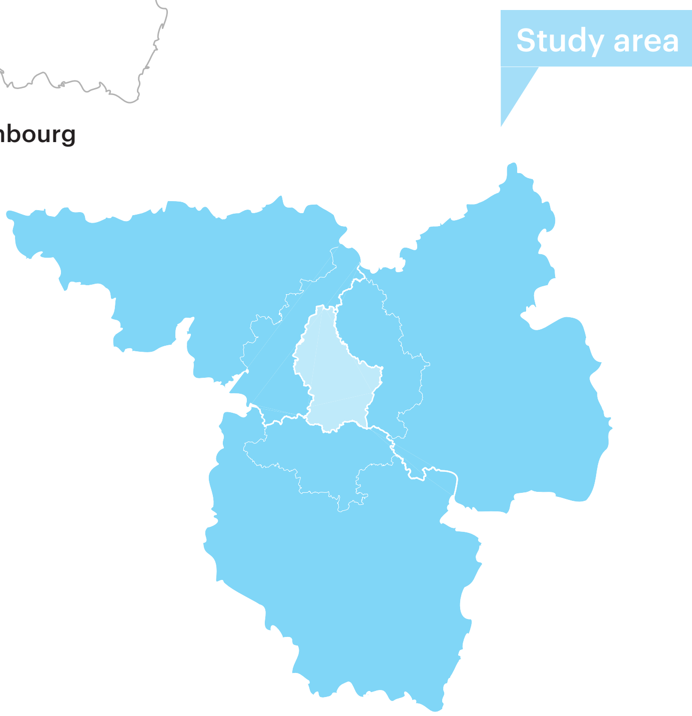
We have tested the application of this project's methodology more thoroughly in the topic of food. In that case, each metric assumption was compatibilized to an equivalent at the Functional Area level, when necessary. As a point of reference, we used data from the Interreg Territorial Development Plan for the Greater Region, Thematic books 1 to 4, from 2018. To leverage the reference data we found (in different scales and levels of detail), we made assumptions that reflect back to solid statistical data from the above mentioned report to support our investigations. Examples of such reference values are the population distribution or land use distribution per region of the Functional Area.



Luxembourg



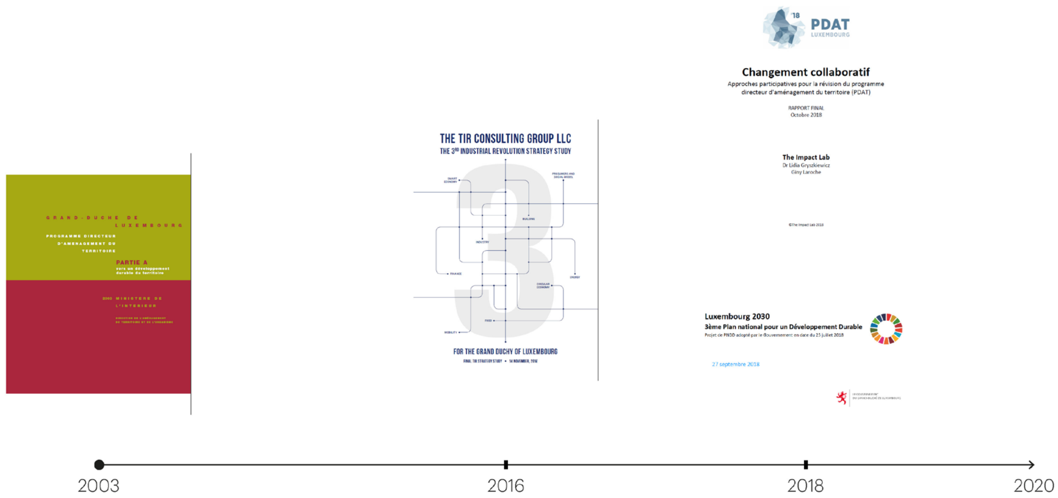
Luxembourg and neighbouring Cantons



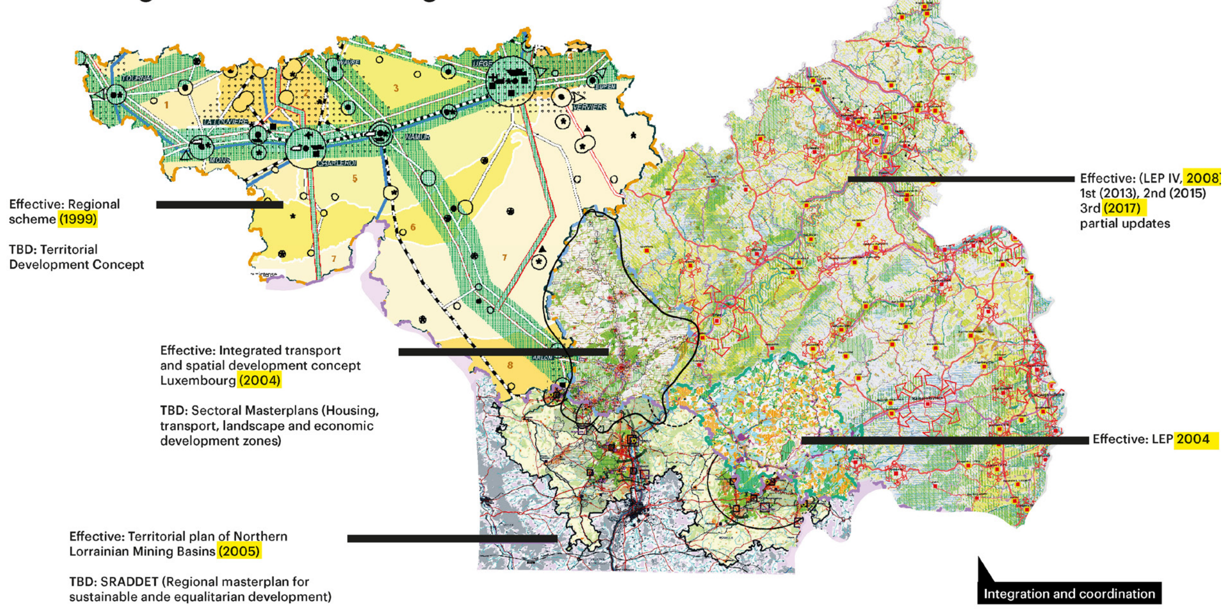
Luxembourg Greater Region

Understanding Luxembourg Functional Area

As part of our analysis we have looked into the local agenda at national and regional level, and encountered the challenge of integrating information across the different administrative areas, the lack of alignment in the chronology of publication of their planning documents and established ambitions.

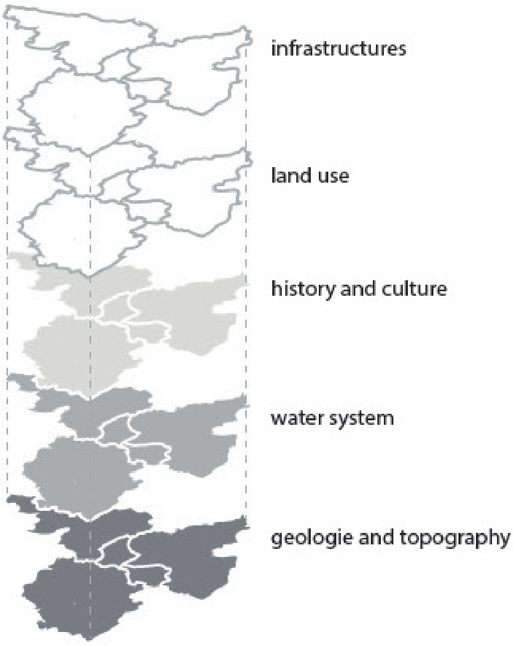


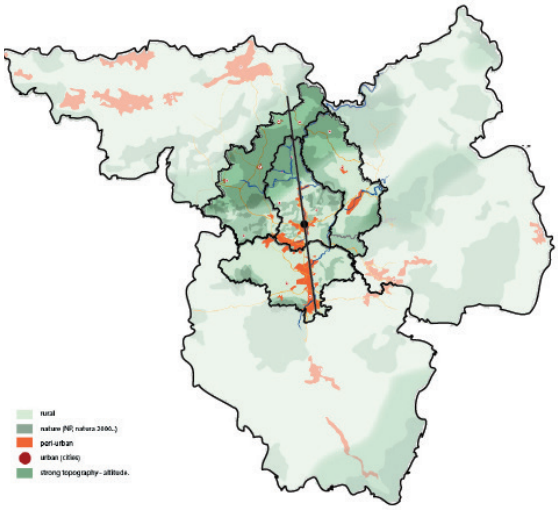
Challenge: Territorial Planning



Interpreting the challenges and opportunities

The layer analysis





What is the identity of Luxembourg?
typicality - fascination - anchor for the dream - chances - common imaginary

pristine landscapes

nature and strong geography : rivers, valleys...

combination of history, modern architecture and nature

dull cities

very connected

contact to nature everwhere

multi-cultural, multi-lingual, very connected to other countries

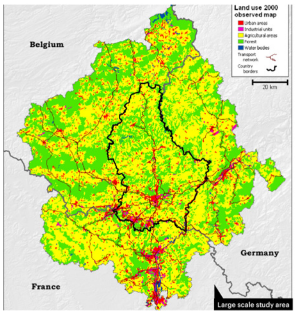
city are “work-place”, few cultural and education offer

small community feeling

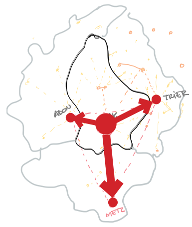
diversity - melting pot

little opportunities for young and countryside

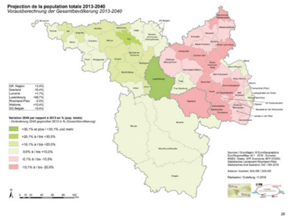
The Functional Region of Luxembourg



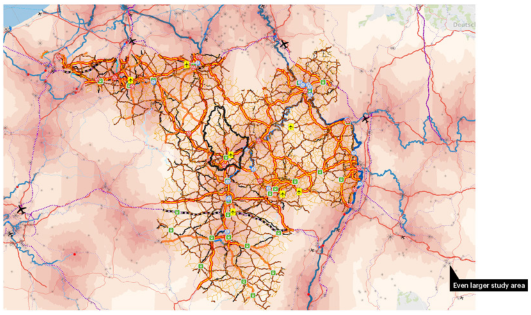
Urbanization tendencies



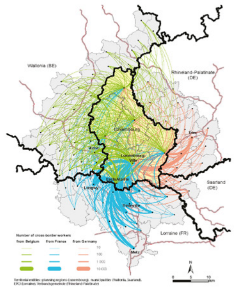
Challenge: Urbanization

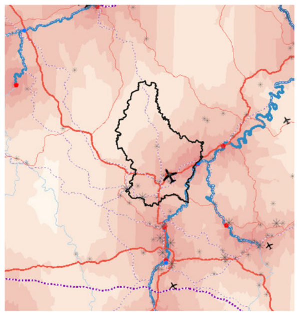


Transportation greater regional level

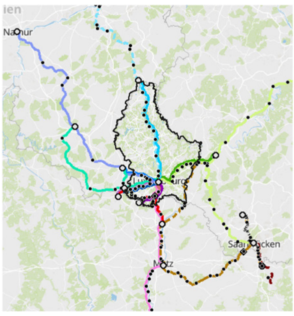


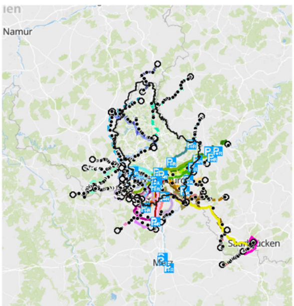
Passenger and Freight Transportation



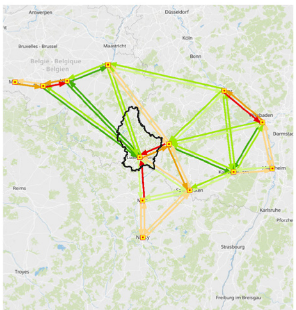


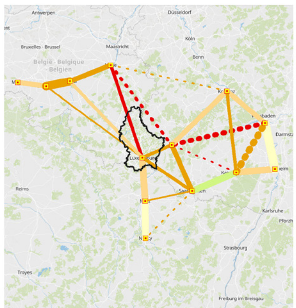
Cross-border rail and bus





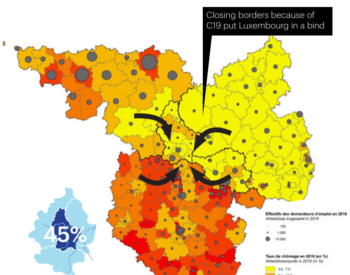
Quality of motorized connections vs. rail connections





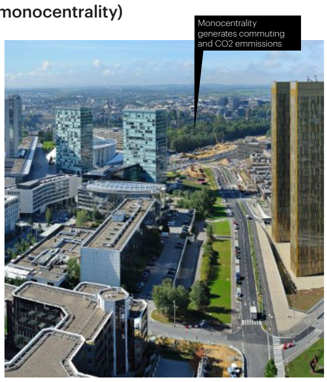
And great economic pole (burdened by its monocentrality)

Employment rate

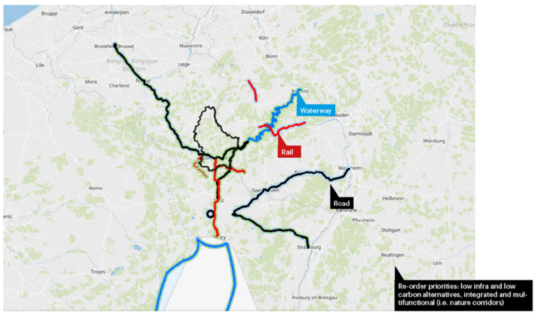


71% of the salaried population of Luxembourg is composed of **cross-border commuters** (45%) and foreign residents (26%).

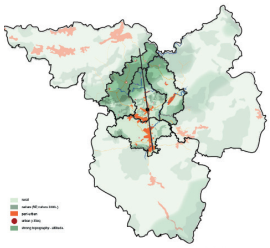
Source: Schéma de Développement Territorial de la Grande Région, CAHIER THEMATIQUE N°3 Développement économique

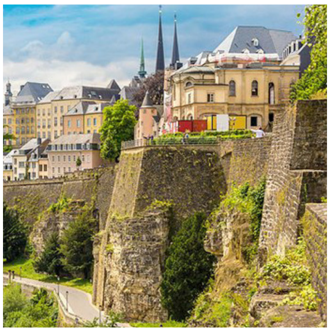


Priority transport projects

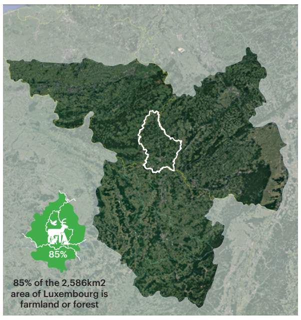


With charming s/m cities, of high-quality life standards (however rigid to change)

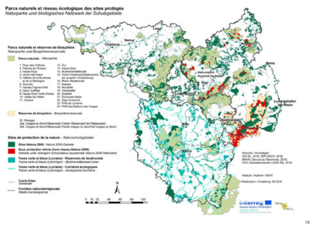


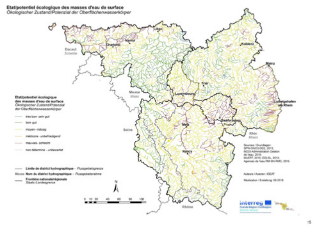


Luxembourg is known for its abundant green and strong geographic features



Challenge: Preservation vs. Agriculture

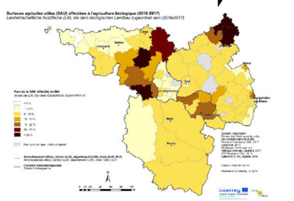




Worst ecological potential near agricultural lands

Agriculture: 52% of the Greater Region

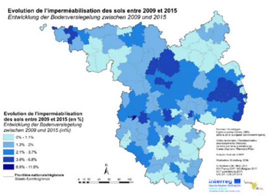
Although not much workforce



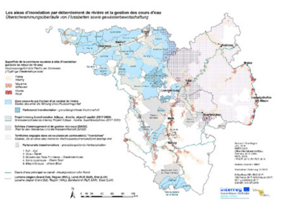
Agri-environmental programs push to integrate the practice of organic farming (MAEC)

So much space dedicated to agriculture: could it be optimized? could it be hightech? could it attract young brains?

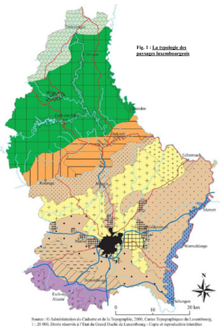
Impermeabilization and floods



Vulnerable where there is more population



Wallonia, Luxembourg and Lorraine have set up river contracts (environmental contracts in France), participatory management structures with the objective of bringing together all the actors (political, administrative, economic, associative or scientific) the same basin or hydrographic sub-basin.

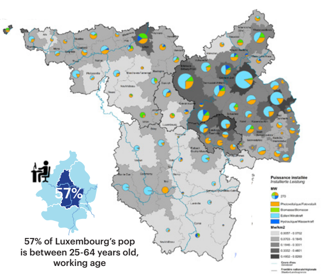


L'Oesling, qui se situe sur la
-limite sud-est du massif ardennais (faisant partie du massif schisteux rhénan)
-paysage de hautes terres schisteuses
-réseau dense de cours d'eau profondément entaillés
-climat tempéré humide, et de plus en plus rude à fur et à mesure que l'on remonte vers le nord,
-les terres acides de l'Oesling sont dominées par des forêts de conifères (épicéas) et des taillis de chênes souvent surannées.
-nombreux villages groupés de petite, voire de très petite taille situés au centre de leurs terres ou dans les vallées encaissées.
-l'activité agricole domine

Le Gutland, situé sur
-l'extrémité nord-est du Bassin Parisien et
-séparé de l'Oesling par une dépression périphérique, présente une organisation bien différente. Son
-climat tempéré, moins pluvieux et légèrement plus doux que celui de l'Oesling, domine -terres sédimentaires structurées par un relief de côtes.
-villages groupés, de taille moyenne et entourés de terres agricoles, sont dominés par plusieurs villes.
-activité urbaine est principalement tertiaire ; l'industrie reste néanmoins très présente, surtout dans le sud-ouest du pays où l'extraction de la minette a généré un paysage particulier.
-la viticulture est présente uniquement dans la vallée de la Moselle – où elle marque profondément le paysage – et quelque peu dans l'arrière-pays de ce cours d'eau.

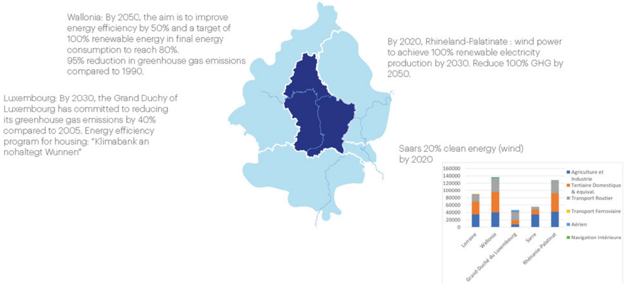
Luxembourg region is on its way to a greener, better, stronger future

Renewable energy production



Source: Schéma de Developpement Territorial de la Grande Region, CAHIER THEMATIQUE N°4 Environnement et énergie

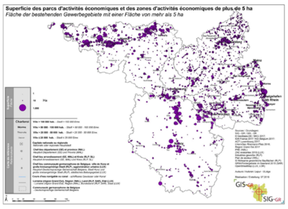
EU Ambition: by 2050, reduce greenhouse gas emissions by 80% to 95%, compared to 1990 levels.



Region	Luxembourg	Wallonia	Rhineland Palatinate	Saarland	Lorraine	Greater Region
Renewable electricity production (GWh)						
Year	2015	2014	2015	2015	2016	-
Hydraulic	112	314	922	93	322	1,763
Biomass	148	1,517	1,135	221	150	3 171
Wind	101	1,437	5,036	490	1290	8 354
Photovoltaic	100	792	1,760	377	222	3,251
Other	0	0	90	4	0	94
Total renewable electricity	461	4,060	8 943	1,185	1 983	16,632
Share of renewables in gross domestic electricity consumption (%)	*7%*	*16%*	*31%*	*13%*	*nd*	*nd*
Renewable electricity production per km² (GWh / km²)	0.18	0.24	0.45	0.46	0.08	0.25
Renewable energy production (GWh)						
Renewable energy production	2,442	13,074	21,869	2 803	9 776	49,964
Share of renewables in gross domestic consumption (%) *5%*		*11%*	*14%*	*4%*	*13%*	*11%*
Renewable energy production per km² (GWh / km²)	0.94	0.77	1.10	1.09	0.41	0.76
Percentage of renewable electric power installed within the territory						
Year	2018	2016 and 2018	2015 and 2016	2015 and 2016	2016	-
Hydraulic	11%	8%	4%	2%	7%	5%
Biomass	9%	22%	9%	1%	3%	10%
Wind turbine	39%	51%	55%	48%	70%	55%
Photovoltaic	41%	19%	32%	49%	20%	31%
Total power (MW)	306	1365	5299	812	1115	9680

But how to address challenges and changes needed to get there?

Sectors of activity



business parks tend to be far from urban centers often located in the valleys by placing themselves more on the plateaus along the highways.

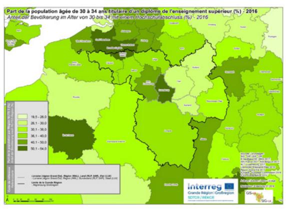
Socio-professional categories of workers in the Greater Region

Slopes	Socio-categories professional	Workforce	Share (in%)	% in 2000 *	Evolution since 2000 *
Luxembourg (data 2011)	Agriculture	4,178	2.2	2.7	- 7.5
	Managers and business leaders	57,297	30.0	21.6	58.4
	Intermediate professions	52,870	27.7	35.7	- 11.5
	Employees and workers	76,734	40.2	40.0	14.6
Rhineland-Palatinate (data 2017)	Agriculture	8 845	0.6	Data unavailable	
	Managers and business leaders	176,081	12.7		
	Intermediate professions	520 830	37.7		
	Employees and workers	675,657	48.9		
Saarland (data 2017)	Agriculture	1,902	0.5	Data unavailable	
	Managers and business leaders	44,445	11.6		
	Intermediate professions	139,071	36.4		
	Employees and workers	196,829	51.5		
Wallonia (data 2016)	Agriculture	25 811	1.9	Data unavailable	
	Managers and business leaders	428,806	32.1		
	Intermediate professions	326,445	24.4		
	Employees and workers	555,848	41.6		
Lorraine (data 2014)	Agriculture	11 451	1.1	1.6	- 27.2
	Managers and business leaders	174,424	16.4	13.9	27.0
	Intermediate professions	257,958	24.2	21.4	21.8
	Employees and workers	622 277	58.4	63.2	- 0.6

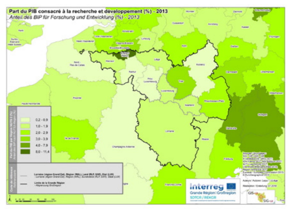
Sources: INSEE Lorraine, Statistisches Landesamt Rheinland-Pfalz, Statistisches Landesamt Saarland, STATEC, IWEPS, 2018. [* 2001 for Luxembourg, 1999 for Lorraine]
Notes: The data are based on different classifications according to the regions: "Klassifikation der Berufe" (KldB) for Germany and Socio-professional categories (CSP) for the other countries.

21

Challenge: Rather low R&D expenditure/synergies

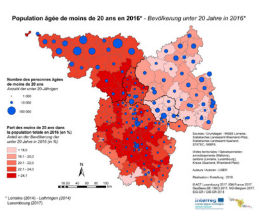


Large investment in eductain



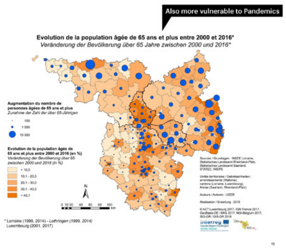
Less than 2% of GDP invested in R&D

Challenge: decline of young population



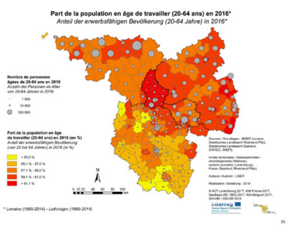
How to continue being attractive to the young?

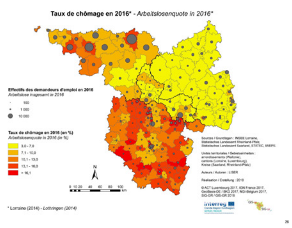
Also more vulnerable to Pandemics



How to prepare to meet the aging population's demand for health, accessibility, well-being?

Challenge: regional balance of opportunities





How to rebalance opportunities to the surrounding cities and relieve the pressure in luxembourg?

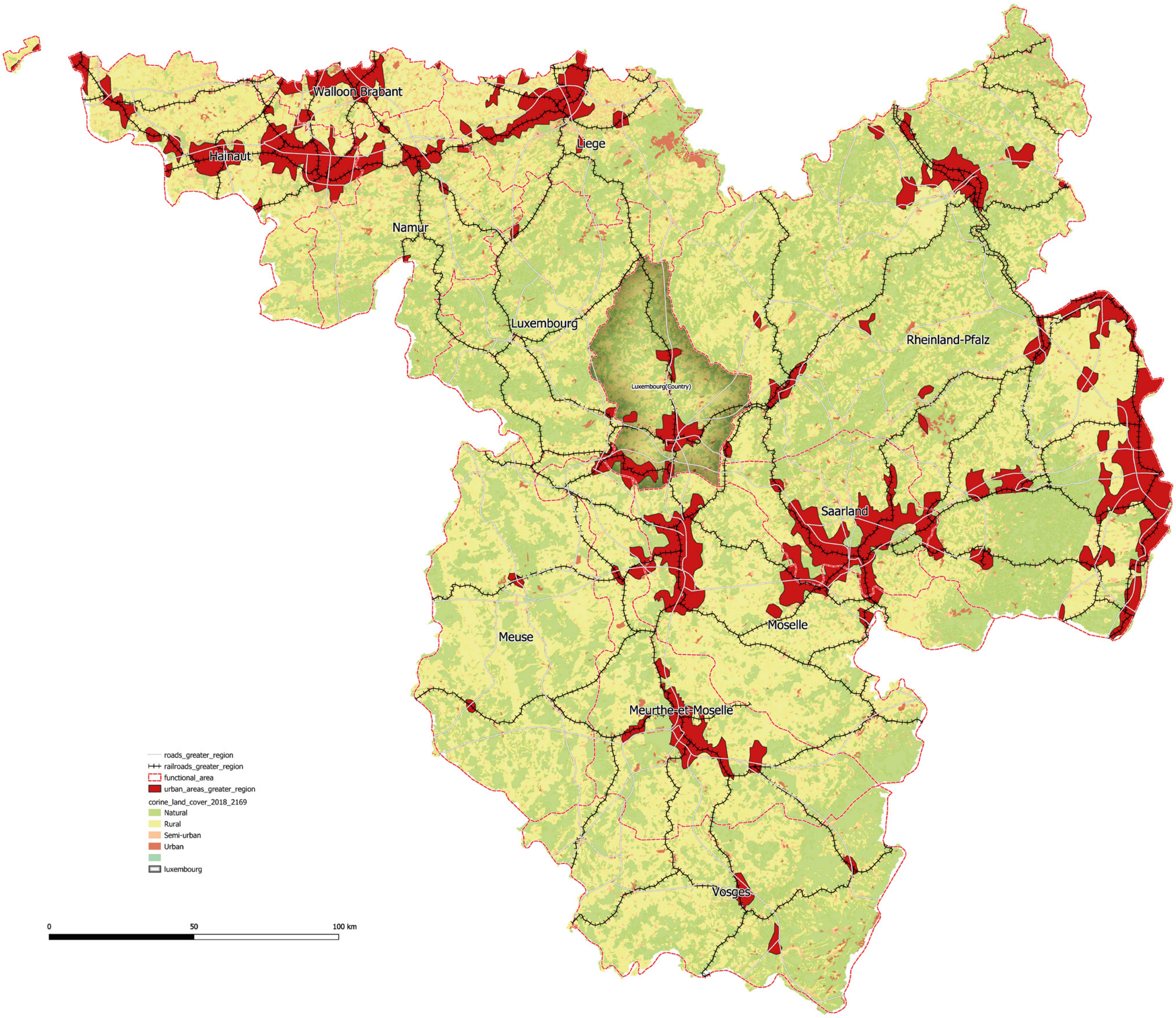
The Study Area Characterization

Beyond lux(e) ANNEX

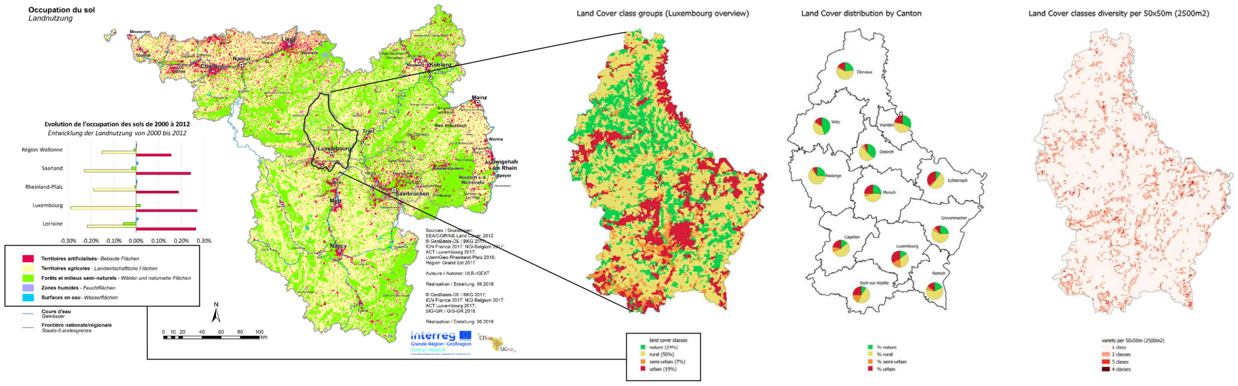
Classifying space for further analysis and actions

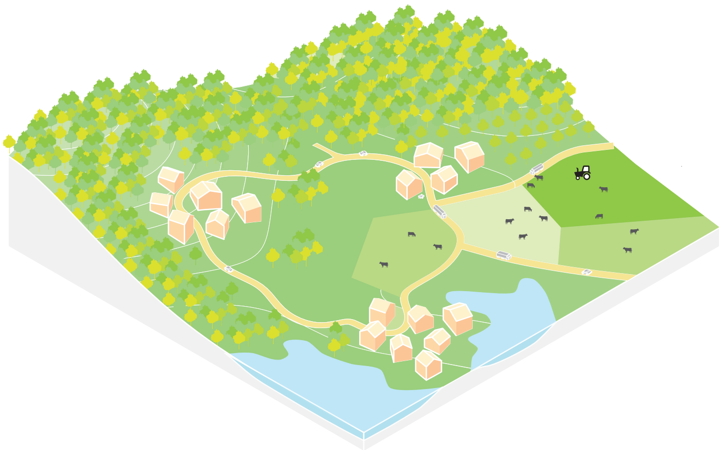
From the initial analysis it was identified that the spatial organization of Luxembourg Functional area follow a pattern of rural areas punctuated by villages and towns. These form a network of cities that sprawl along rivers and infrastructure such as road and rail lines.

With that in mind, we have classified the landscape in 4 typologies: Urban, Periurban, Rural and Nature. Such classification help structure and focus the actions defined to facilitate transition in the different themes theme (food, water, energy, mobility, waste). We recognize and work with the correlation of actions applied in a spatial typology, and its effects and consequences on another. Mostly, these are a tool to define targets in space to apply an action or mix of actions depending on the typologies represented within a spacial cluster.



Spatial analysis

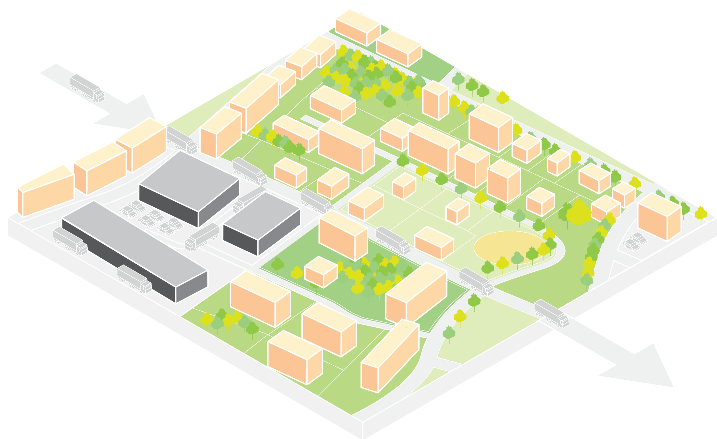




Nature

Rural

Periurban



Urban

Thematic Metrics

2

Food

The regenerative target for food includes reductions that mean as much as 29% or the current CO2e in the Functional Area. Actions include phasing out meat-lover habits, renaturate 27% of the territory, reduce importing and exporting food from far away and establishing agroecological practices to replace agribusiness.

01 TARGET	02 GAP	03 ACTIONS (TILES)				
REGENERATIVE GOAL	GAP (low,high)		03 ACTIONS		Quantifications	Tools
A HEALTHY PLANT- BASED DIET						
Phase out meat-lover habits	**Food consumption habit: Meat Lovers 75% of the population**	1.1	Nutrition transition to Reduce CO2			
			Change Food Habit to reduce meat consumption	Q1	from 2% vegan population to 100% vegan	veganism
			Decrease CO2 by eliminating animal-products	Q2	from 30mt CO2 current habits to 17 Mt CO2e vegan habits	substitute animal farming with plant-based farming
			Increase forest area	Q3	**70%** increase in forest area	
			Potential CO2 reduction of food transition	Q4	44% reduction in t CO2	add area of forest to capture carbon
		1.2	Repurpose land per food habit			
			Reduce land use of pasture and meat production	Q5	from 51% dedicated to pasture to 0%	eliminate pasture land use
			Potential reduction in land requirement by shifting food habits	Q6	from 3x agruculture land (import) to 1/2 of agriculture land	redistribute types of production land
		1.3	Change what is produced locally			
			Rebalance production of plant-based foods	Q7	tonnes produced	agroforestry, urban agriculture, edible garden
			Increase awareness about food chain and waste	Q8	% of population that is aware	proximity to production (visibility), eductaion, media, bonus/onus incentives
			Reinterpret what is edible	Q9	tonnes of alternative foods	eductaion, media, bonus/onus incentives
B LOCALIZED SYSTEM						
Reduce import/export in 37%	**Imports from far away are 37% of the total**	2.1	Optimize production to strengthen local supply			
			Rebalance crop-animal ratio according to local ecosystem	Q1	tonnes of food produced per type	agroforestry
			Produce more in the same space	Q2	yeld per ha	precision agriculture tecnologies
			Reduce water use	Q3	x% less water	smart irrigation, water circularity
			Reduce energy use by creating synergies	Q4	50% less energy	place farms close to highways or industries to use theis energy surplus
			Repupose organic waste with compostage	Q5	% less food waste	place urban edible gardens close to restaurants to use their organic waste
		2.2	Shorten the supply chain			
			Minimize import pressure	Q6	land requirement deficit	ecotaxes on CO2 impact of transport
			Minimize yield production to export	Q7	tonnes export	social taxes for non-essential exporting
			Reduce C02 emmited in food transportation	Q8	tCO2e food transportation	prioritize rail and waterways, and enhance access
			Reduce food waste lost in transportation	Q9	tonnes of food lost in transportation	redistribute landuse and mix farm and city
			Reduce food processing and packaging	Q10	tonnes of processed food	ecotaxes on packaging
			Increase access to local fresh food	Q11	Fresh food market number , frequency and coverage	streets and avenues closed for temporary events
			Maximize urban agriculture	Q12	km2 of urban ag	edible gardens using openspace, rooftop garden
C AGROECOLOGY						
50% of agrobusiness to change into agroecologic	**"foodprint" of agrobusiness due to 51% agriland for pasture and cows**	3.1	Change from agro industry to agro-ecology			
			Maximize reforestation of agriculture land - pasture + cultivated cropland	Q1	food classes/ha	agroforestry
			Maximize perenial crops productivity	Q2		environmentclimate driven design of production spots
			Maximize carbon capture	Q3		prioritize species with high carbon capturing capacity
		3.2	Increase productivity of agroforestry			
			Increase productivity of organic farming	Q4	100% of organic farming	bio-fertilizers, climate design
			Introduce eco-corridors into farmland	Q1	km of eco-hegdes	hedges
			Optimize soil health for fertility	Q2	soil indicators	soil ploughing
		3.2	Eliminate fossil fuel and artificial fertilizers			
			Use green energy machines	Q7	expenditure in e-trucks	provide electric machinery charging spots
			Increase poeple-based farming	Q8	worforce in agro	techical and high education in farming
			Decrease use of artificial fertilizers	Q9	tonnes of fertilizer	proximity to organic waste makers (industry and restaurants)
			Reduce CO2e from fertilizer production	Q10	tonnes or % of crops that use it	
		3.4	Relief urbanization pressure on productive landscapes			
			Fix the urban fabric perimeter	Q11	km2 of urbanized area	planning policies
			Accomodate population growth within existing urban areas - densify and redistribute centralities	Q12	People per sqm	densification, infill, adaptive reuse, mixed landuse

actions + tools + scales + phasing *(full calculations in excel)*

	04 METRICS							05 INTEGRAT	06 GOVERNA	07 PHASING (SECTIONS)		
Scale	Positive outcome				Negative outcome			Mitigation (T	Priority	2030	2040	2050
										Cumulative milestones		
region rural region rural rural rural + urban behaviour behaviour	**Reduce 10% of total C02 emissions of the Functional Area** 44% CO2 reduction in foodprint, from changing to vegan habits	Reduce 64% of the land demanded to supply non-plant based food habits (possibility of phasing out importing and expoting)	Repurpose 51% of agriculture land to sustaibable uses (enhanncing water permeability , microclimate, biodiversity)	30% decrease of N2 in ground water from livestock effluents (enhancing water quality and biodiversity)	20% economic loss from meat processing and preservation	95% of the population will need to change food habits	"Transfering" the meat and dairy products to importation, creating a bigger footprint	Growth of Fruit and Vegetable industry Develop alternative Policies to avoid "transfering" the problem Redirecting budget to upgrading	75% meat lovers 18% flexetarians 2%Vegetarian Largest populatio Rhineland and Wa Lorraine Saarland Luxembourg	Rededicate land and production, change supply, incentivise Meat lovers turn flexetarian = 66% of "chnaging food habits" Target achieved	Public sector facilities (schools, hospitals, etc) provision of vegetarian meals only MeatLovers + Flexetarian turn vegetarian = 82% "chnaging food habits" Target achieved	(Heavy taxation in carbon heavy foods, especially meat & dairy products) Meat lovers + flexetarian + vegetarian turn vegan = (100% of "chnaging food habits" Target achieved (-44% CO2 emissions)
rural+peri+urban periurban urban	**Reduce 3% of total C02 emissions of the Functional Area** 33% CO2 reduction in the emissions related to international transportation and trade	Reduce dependency on 37% of imports coming from far away (Resilience to "lock-down" stresses like COVID 19)	Reduce burden of 24% of exports going to far away destinations	Reduce food waste in transportation Increase nurition factor and enhance public health	37% economic loss from import	24% economic loss from export	Access to Diverse foods, available year round	Invest in local productivity technologies Change to seasonal and conscient food consumption Export knowledge and technology	37%imports comi 24%exports comi	Intl food transportation only thorugh electric vehicles and clean modes = 18% of "food trade emission" reduction target achieved)	Cut imports of beverages and stimulants (coffee) = 30% of "food trade emissions" reduction target achieved	Cut imports of vegetable & oil seeds (soy) = 100% of "food trade emission" reduction achieved
natural + rural rural + perirban rurual+ periurban region region rural rural region urban urban	**Reduce total of 15% of total CO2 emissions of the Functional Area** Reduce 2 MT CO2e emission from chemical fertilizers Reduce17 MTCO2e emissions by capturing carbon with reforestation	Not emmit 6% of CO2 from pasture/animal farming land use Dedicate 17390km2 of pasture to forest or afroforest in periurban areas	Increase Water quality by reducing 50% of N2 in groundwater from chemical fertiliezers (increase ater quality, biodiversity, reduce eutrophication risk)	Temperature decrease of 3°C in urban centers with reforestation in periurban areas	Long time wait for afforestation	Productivity of organic farming and agroforestry sustems is lower in comparison to intensive agriculture	Change from machine intensive, large farms to human-intensive smaller farms would also impact economy and employment relationships	Invest in agroforestry productivity technologies Incentivize a stronger job market arund organic farming and other sustainable parctices	Chemical Fertilize Pasture land-use	Cut down the use of chemical fertilizers and support (subsidies, tax abonemnent) sustainable agriculture practices = 11% of 'agroecology target"	Convert an area of 17390 km2 that today is dedicated to pasture, into forest = 58% of "agroecology target"	Convert arable land into agroecology stetem= 100% of agroecology target

Energy

In 2015, with the Paris Agreement, the international community set itself the objective of limiting average global warming well below 2 degrees from pre-industrial era, pursuing a maximum temperature increase of 1.5 degrees. Unequivocally, it shows that to reach the target by the middle of the century, global CO2 emissions must be reduced to a net balance of zero.

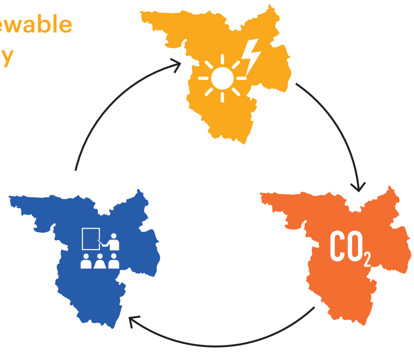
In 2016, the country of Luxembourg produced around 9m T of CO2 and now the plan is to reduce it by 55% by 2030 and to reach the net balance of zero in 2050. Increasing the air quality (reducing the pollution emissions connected to buildings, mobility and industry), following the climate changes (biodiversity integration in urban areas, limiting the

01 TARGET	02 GAP	03 ACTIONS (TILES)				
REGENERATIVE GOAL	GAP (low,high)		03 ACTIONS		Quantifications	Tools
A ENERGY AWARENESS						
100% mandatotry educational plan in schools for Sustainability by 2030 **50% of cars being electric by 2030** **25% cars being electric by 2040** **25% cars being electric by 2050** **40% of Building riqualifcation by 2030**	**GAP:** **84.6% of Building completed before 2000 need to be efficiently renovated**	1.1	Change People habits to reduce Energy consumption			
						App for personal simultaneous consumption and behaviour
			Defining Energy Budget pro capita and Monitoring	Q1	# KWh/pers-a according to age and activity	
					% less Energy and CO2e waste	App for personal simultaneous consumption and behaviour
					100% population that is aware	information/media/education/Smart indicators
			Defining maximum space for living pro capita	Q2	# m2/pers	Taxes payment for extra space
					# increase in forest area	Urban planning
					% reduction in carburants	Policies, incentives for electric vehicles
			Promoting Sustainable ways of transportation (bike / e-bike / e-car /..)	Q6	% reduction for CO2 and other Air pollutants	Air quality
					% reduction for streets width	Urban adapting plan
					% less stress for traffic and parking	Quality of life - statistic
		1.2	Change Building approach to reduce Energy consumption			
			Designing with a Sustainable and Klima based strategy	Q1	Achieving Comfort (Visual and Thermal / indoor and outdoor) with as much as possible of PASSIVE strategies	Climate integrated based Design
			Change of Comfort Standards	Q2	from 26°C to 29°C + Air movement, for Cooling	Energy credit
			Promoting Buildings riqualification instead of New Constructions	Q3	# less Embodied Carbon	LCA + LCC (Life Cicle Analysis + Life Cicle Cost)
					# less land use	Urban planning
					# increase in forest area	Urban planning
			Mixed Building Program (residence+office+industry+education)	Q4	% less energy waste / production / transportation	Smart connected Energy grid
			Proximity to open green land	Q5	% reduction of Heat city islands (hence % reduction for Energy demand for cooling)	Urban planning
B 100% RENEWABLE ENERGY						
2020: only 11% of Total Energy Consumption is produced from Renewable sources **TARGET:** **+21% (of the total Energy Consumption) will come from Renewable Sources (solar +wind+geothermal+hydro-poer) by 2030** **+68% (of the total Energy Consumption) will come from Renewable Sources (solar +wind+geothermal+hydro-poer) by 2050**	**GAP:** **89% of the total Energy Production is not renewable**	2.1	Energy production			
			Conversion form fossil sources to Renewable sources		% less CO2 emitted	
						add area of forest to capture carbon
			Identify and Localize energy production sites according to the Local Potential	Q2	% of Wind turbines on the North Area	Energy Balance accoridng to Population growth
					% of Geothermal system on the South Area	Energy Balance accoridng to Population growth
					% of Hydropwer system on the East Area	Energy Balance accoridng to Population growth
					% of Solar Panels	Energy Balance accoridng to Population growth
			Synergy with Agriculture	Q3	% less land use	Urban Planning
					% water consumption for irrigating fields	Smart intregration of systems
			Decentralized and shared Ownership system	Q4	% more social and community agreement	Policy, bonus
			Centralized Energy Prduction system	Q5		
					% less energy waste / production / transportation	Smart connected Energy grid
					% reduction in public network overload peaks	Smart connected Energy grid
					% more Resilient system	Smart connected Energy grid
			Dara center buildings connected to the system	Q6	% less waste heating (free heating from the data center can be used to heat up residential areas)	Smart connected grid Urban planning for mix used areas
			Supermarket and Food Industry connected to the system	Q7	% less waste heating (free heating from the data center can be used to heat up residential areas)	Smart connected grid Urban planning for mix used areas
B CARBON NEUTRALITY						
TARGET: **(assuming NO Energy Storage in 2020)** **+32% use of Energy Storage by 2030**	**GAP:** **100% of Energy Storages (Thermal and Electrical Energy to be located)**	3.1	Energy storage			
			Integration of Energy Storage for Electricity and Thermal Energy (geothermal / gravity based / power to gas / magnetic /..)	Q1	% redution in importing foreign Energy	Policy
					% reduction in public network overload peaks	Smart connected Energy grid
					% fluctuation reduction for Energy price	Policy, Governement

water consumption per person, reducing the impermeable soil), increasing waste management and reducing the energy consumption for building, mobility and industry and raising renewable energy use.
Due to the significant climate changes, it is rational to think that the country will soon move towards an autonomous and independent strategy for energy supply, with high efficiency and zero emissions.

	04 METRICS							05 INTEGRAT	06 GOVERNA	07 PHASING (SECTIONS)		
Scale	Positive outcome				Negative outcome			Mitigation (T	Priority	2030	2040	2050
human human country country country regional city regional human	Increase Health and wellness of Population	Reduce traffic and rlative People time waste			New Habits to be adopted by citizens may meet with hostility			Implement the potential in between Efficient Mobility and Sustainable Energy	Set a maximum Energy Budget pro capita	50% of cars are electric in the Functional Area	75% of cars are electric in the Functional Area	100% of cars are electric in the Functional Area
city country country country country regional country	Limit new emissions of CO2	Reduce Land use	Reduce Materials use						Energy and Waste educational plans integrated in school programs	40% of Buildings is efficiently refurbished	70% of Buildings is efficiently refurbished	100% of Buildings is efficiently refurbished
country country country country country country country human regional regional regional city city city city	**Reduce 68% of total CO2 emissions of the Functional Area**	Reduce 60% of land use for Energy production Increase Energy production Efficiency	Increase sense of identity within a community	Reduce use of water for agriculture	High initial cost of investement	Wind turbines can have an acoustic impact on the environment		Implement the potential in	Conversion form fossil sources to Renewable sources Identify and Localize energy production sites according to the Local Potential	Use of Renewable Sources from Energy Production will pass from 11% to 32%	Use of Renewable Sources from Energy Production will pass from 32% to 66%	Use of Renewable Sources from Energy Production will pass from 66% to 100%
country regional country	Increase system Resiliency	Increases the robustness of the system	Independence from economic market fluctuations		High initial cost of investement				Electrical Storages Thermal Storages	Use of Energy Storages for 32% of Total Energy Consumption	Use of Energy Storages for 66% of Total Energy Consumption	Use of Energy Storages for 100% of Total Energy Consumption

... towards a (re)generative energy system



A regenerative energy system is entirely based on renewable resources, combined with a solid on-site storage system, which provides a high energy autonomy level.
For this reason, the following objectives are aimed at: Energy Awareness for Energy Reduction: change People habits and Buildings approach to reduce Energy consumption. Energy Production: 100% through Renewable sources. Energy Storage: 100% Carbon Neutral on-site.

the gap in energy

The renewable energy industry is currently at its own infancy time; even though a lot of studies and improvements have been done in the last decades only 11% of energy was produced by renewable resources in 2015.
Solar and wind resources can produce the most significant amount of energy but currently only 5.5% of worldwide production comes from them. The main reason is that their highest production happens during the lowest demand time (solar energy is maximum during the day, when the demand is low, and wind is normally stronger during night, when again the demand is low). To be truly effective, energy produced needs to be stored.
In 2017, the worldwide electrical energy stored was around 176 GW, that represents less than 2% of the world's electric power production capacity. Particularly, in the same year, USA was able to store only 2,2% of its production capacity, Europe 10% and Japan 15%. In any case, the European commission is aiming for 27% of renewable energy storage by 2030.
Renewable energy production in Luxembourg comes mainly from Wind-Power plants, around 39% mainly form the North area, and from Solar plants, around 41%. A smaller percentage comes from biomass (~9%, mainly from the South) and Hydraulic (~11%, mainly from the East area of the country).
The Not-renewable energy comes mainly from fossil fuel (~65%) and nuclear power (~24%).
Taking into account the population increase (from 615000pers to 790000pers -- +23% in 30 years), total energy consumption will increase accordingly.

the actions in energy

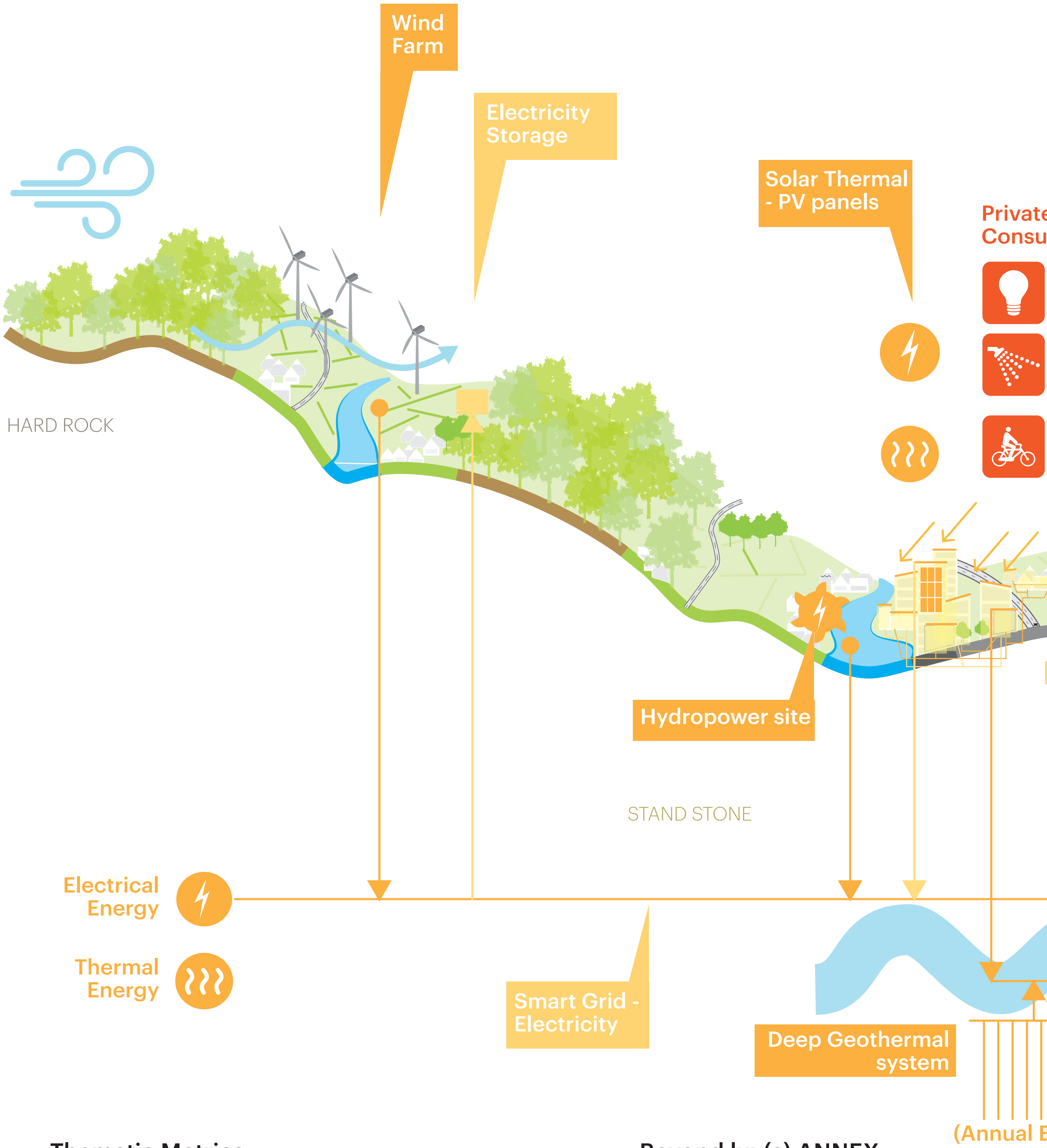
Energy Awareness for Energy Reduction
Aiming to reduce the total Energy consumption, People habits and Buildings approach need to be changed. Everybody will have a certain amount of Energy (daily or monthly based) according to the age and the kind of activity. This amount represents a maximum limit pro-capita that can be used for living, working, moving, training, etc. Any extra demand for Energy will have to be disincentivised through the payment of taxes, for example. The consumption would be monitored through an App, on the smartphone, giving dynamic and simultaneous energy consumption values. Space for living and working, as well, needs to be regulated: a maximum area per person should be assigned. This strategy can easily reduce the land use for urbanization: less urbanization means less construction, less materials, less CO2 emissions, less energy consumption for Building (heating/cooling). All of this brings to the possibility to increase the forestry areas.
Strategies for buildings will change as well. Requalification instead of new construction should be the new rule. This can happen only after checking the real potential of the existing buildings, through a LCA (life cycle analysis) and a LCC (life cost cycle). In fact, existing buildings already contain a big amount of embodied carbon; a policy of requalification is fundamental to avoid waste material, waste CO2 and waste energy. Integrated design (Architecture + Klima Engineering) is crucial to maximize the free benefit, already passively existing, to achieve Comfort, without wasting energy and increasing the CO2 level.
Indoor and Outdoor Comfort range will be based on new standard, slightly wider the existing ones. This strategy allows us to reduce energy consumption and CO2 emissions without compromising the human comfort. For example, in summer, in an office space, it will be possible to set the temperature at 29°C, instead of the standard 25-26°. In fact, 29°C + low air movement (~1m/s) still represents a comfortable condition for working (activity in the space, clothing level, metabolic rate are parameters to be evaluated accordingly).

Energy Production: 100% through Renewable sources
On the country scale, 89% of the current energy production is coming from not renewable sources. The first action will be to convert the fossil and nuclear sources in renewable ones. The North Area of the country has a high potential for Wind Farms as well as the South Area (Luxembourg city) has a great potential for Geothermal sites. Solar panels (thermal and PV) will be located on buildings roofs and facades to increase as much as possible the energy production in the cities. They will be also integrated in other sectors, such as agriculture for example, creating synergies and advantages. In fact, implementing Photovoltaics panels on agriculture fields reduce the land use and does not affect the mutual production. Furthermore, the Pv-covering on top of the fields reduce the direct solar radiation, limiting the water evaporation. Hence, the water consumption is reduced too. At the city scale, all the buildings will be connected to a smart energy grid: energy will move back and forth form production sites to consumption sites according to the urban density. In fact, normally, high density sites require a big amount of energy that cannot be balanced onsite; at the contrary, low density neighbourhood can produce more than what they need. For this reason the grid is fundamental to have a connected and smart system. Data centre, like IT Hub for example, will be part of the grid. They produce a huge amount of heating that can be used to heat up residential or office areas, almost for free.

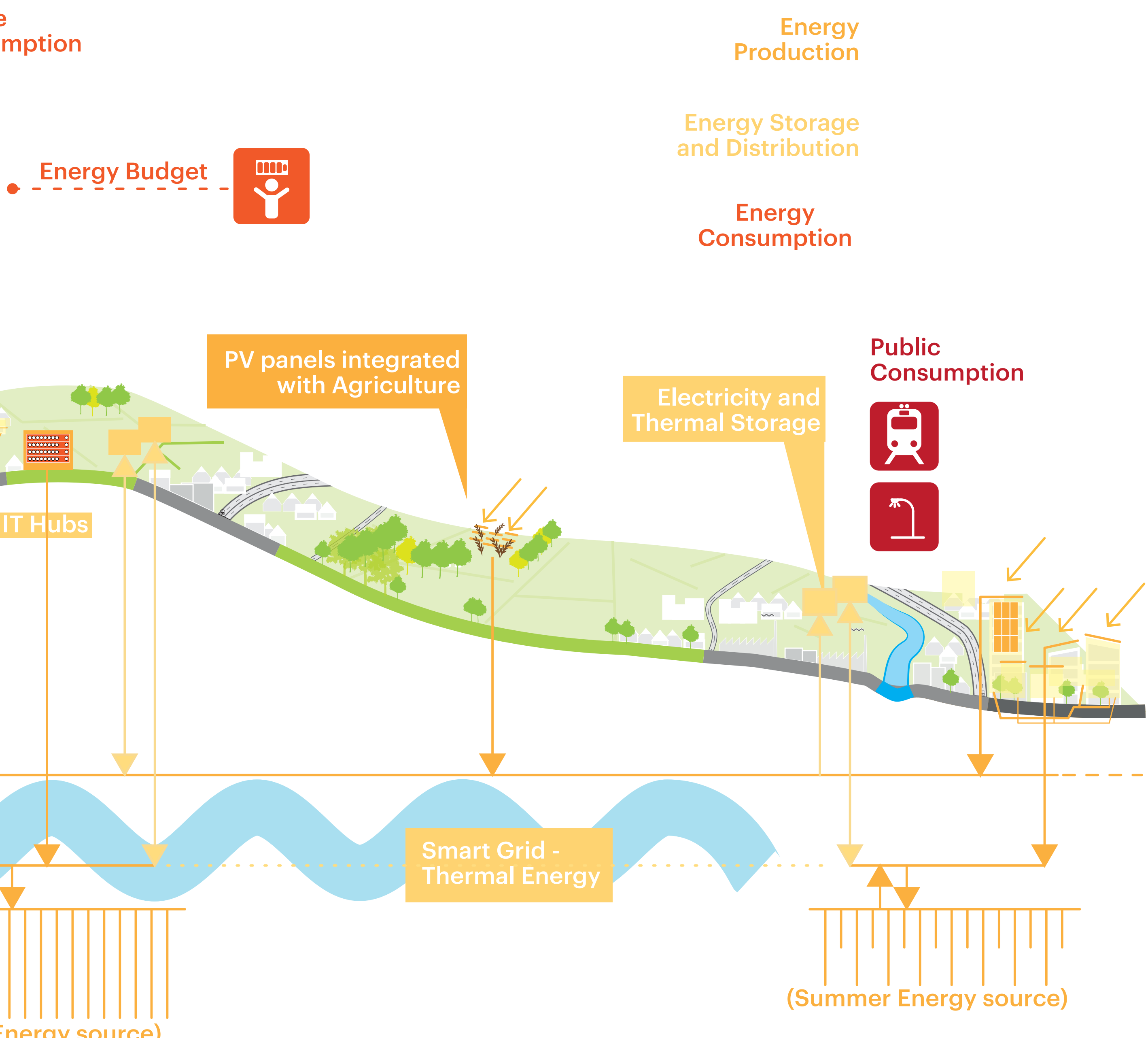
Energy Storage: 100% Carbon Neutral on-site.
Carbon Neutrality is the main goal of the Paris Agreement and of the Luxembourg Transition. We should be aware that aiming to In order to reach the carbon neutrality on site, a solid storage system is required, for both thermal and electrical energy. Carbon neutrality, that mainly means "zero CO2 emissions", can have a different range of autonomy: from 0%, where there is no storage on site and the public grid connection is needed to exchange energy during maximum and minimum production periods, to 100% when there is a storage system and the connection to the public grid is needed only for back up. For both of them the energy production is on site. Aiming to the maximum autonomous system, even if it is more expensive than the standard case, it provides an independent management from the economical energy fluctuations market.
Energy storage systems allow the seasonal balance between energy production and demand. The system generates a surplus of energy during summer season, taking advantages of the greater availability of solar radiations; the extra energy is stored in a combination of several systems, according to the different needs (thermal and electrical), located homogeneously along the cities and their buffer area.

metrics and phasing

All the mentioned actions lead to the total reduction of CO_2 emission by 2050 and to the conversion of the Total Energy production through renewable sources.



According to the Paris Agreement and the European Council, before touching the goal of 0 CO_2 emission by 2050 we should be able to reduce the CO_2 emissions by 55% by 2030, compared to the 1990 value. This is representative for dividing the process in two different phases: the first 10 years (2020-2030) in which the curve of reduction will move from 9mT of CO_2 (current value for 2016) to 4.05 mT of CO_2 in 2030, and the second phase (2030-2050) I which the curve will pass from 4.05mT of CO_2 to 0. All the actions will be scaled down according to this weighted timeline.



Water

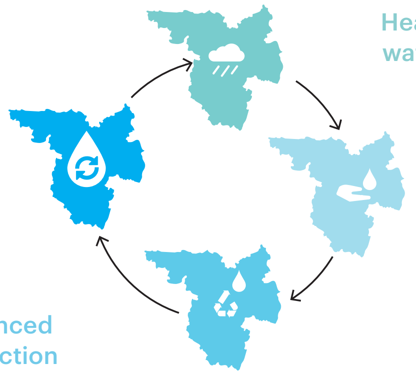
In order to provide an accurate assessment of the Luxembourg water system, it is important to look at future projections. Climate change and domestic trends can greatly influence the sustainability of a water system. For Luxembourg, projections of climate change include a different seasonal distribution of precipitation. The overall precipitation amount will remain more or less equal; but the seasonal fluctuations will be higher. Very simply put, this results in less rainfall in summer and more rainfall in winter. This implies that the availability of water in the top soil in the growing season will be less, as much of rainfall runoff is drained by hard rock formations in Luxembourg's soil. It is paramount, but difficult to buffer the extra rainfall in winter for use in summer. As precipitation will fall with

01 TARGET	02 GAP	03 ACTIONS (TILES)				
REGENERATIVE GOAL	GAP (low,high)	03 ACTIONS		Quantifications		Tools
A LOCAL (RE)USE OF WATER						
	20,200,000 m3/year of drinking water is transported across the country					
TARGET: By 2050, all water used in urban areas is sourced locally		1.1	Create local buffering capacity near urban areas			
			Construct small basins near urban areas	Q1	525000 m2 open water	structural changes to water system
			Retain water on private lots	Q2	130100 m3/year	subsidy for water buffering
		1.2	Centralize waste water treatment			
			Local reuse of treated water, instead of drainage	Q3	17625000m3/year	policy change
			Produce biogas with sludge	Q4	16000000kWh/year	structural changes to WWTP
		1.3	Reduce dependency on Esch-sur-Sûre reservoir			
			Increase extraction near places of high demand	Q5	1929900 m3/year	construction of new extraction points
			Use pipeline from reservoir to Luxembourg only in emergencies	Q6	20200000 kWh/year	policy
B HEALTHY GROUNDWATER RECHARGE						
TARGET: By 2050, there a healthy groundwater recharge, capable of meeting demand and preventing oxidation of organic material.	~90% of runoff is drained quickly.					
		2.1	Reduce soil sealing			
			Construct permeable pavement in urban areas	M1	5000000m2 permeable pavement m3 infiltration per year	policy; making water infiltration obligated
			Construct infiltration facilities	M2	1000000m2 infiltration facility m3 infiltration per year	policy; making water infiltration obligated
		2.2	Reduce fast drainge component			
			Reduce stream discharge in high areas where possible	M1	2000000m3/year	structural changes in streams
		2.3	Maintain high groundwater table in wetland areas			
			Prevention of oxidation of organic material	M1	2-3% of total LUX CO2 production (estimation)	policy; structural changes in streams
C GOOD WATER QUALITY						
TARGET: By 2050, both groundwater and surface water in Luxembourg has a 'good' qualitative status.	Both groundwater and surface water quality are rated as 'insufficient'.	3,1	Prevent adverse effect of industry on water quality			
			Forbid using groundwater/surface water for cooling	M1	1 degrees Celsius	subsidy for change in production processes
		3,2	Purify water before infiltration			
			Construct bioswales	M1	80%reduction in nutrient load [mg/l]	policy; making water purifcation obligated
			Construct helophyte filters	M2	80%reduction in nutrient load [mg/l]	policy; making water purifcation obligated
D BALANCED EXTRACTION OVER THE YEAR						
TARGET: By 2050, water consumption in Luxembourg is brought back to European average	The gap between Luxembourg and the EU is ~80 liters/person/day.	4,1	Discourage water usage in summer			
			Seasonal fluctuation in water price	M1	2350000m3/year	policy
			Seasonal ban on high water consumption (for gardens etc.)	M2	2350000m3/year	policy
			Lower boundary for groundwater extraction permit requirement	M3	2350000m3/year	policy
		4,2	Reduce agricultural groundwater demand			
			Save water by switching to drip irrigation	M1	40000m3/year	subsidy for more efficient irrigation
			Use surface water instead of groundwater pumping	M2	72000kWh/year	subsidy for change of sourcing

more intense peaks, the 'fast' runoff component (drained by streams) will increase, which further reduces the potential aquifer recharge. Soil sealing exacerbates this issue. Higher temperatures in summer result in more evaporation, which puts another strain on the water balance in summer. Currently, the quantitative state of Luxembourg's water system is good. However, with increasing precipitation and decreasing aquifer recharge, chances are that in the future there will be a deficit in summer. On top of climatological changes, domestic trends such as an increasing population count or a culture shift towards a higher water usage, might put a further strain on the water balance. This aspect is to be considered for Luxembourg.

	04 METRICS		05 INTEGRAT	06 GOVERNA	07 PHASING (SECTIONS)		
Scale	Positive outcome	Negative outcome	Mitigation (T	Priority	2030	2040	2050
		negative things summarized below:		General urgency i			
	Total water saving:						
urban, peri-urban	20.200.000 m3/year	less land for other functions.					
urban		-					
	Total energy saving:						
peri-urban	30044045 kWh/year	possibility for eutrification (water quality decline)					
peri-urban	~7000000 kg CO2	more transport of sludge via road (more trucks)					
urban, peri-urban		local exhaustion of sources					
region		-			5%	25%	100%
urban		more expensive road construction?					
urban		more expensive road construction?					
region		changes to local ecology/biodiversity					
region		changes to local ecology/biodiversity			5%	25%	100%
region		possible less production by industry					
urban		-					
urban, peri-urban		-			5%	75%	100%
cultural		public opinion					
cultural		public opinion					
cultural		public opinion					
region		-					
region		changes to local ecology/biodiversity			75%	100%	100%

... towards a (re)generative water system



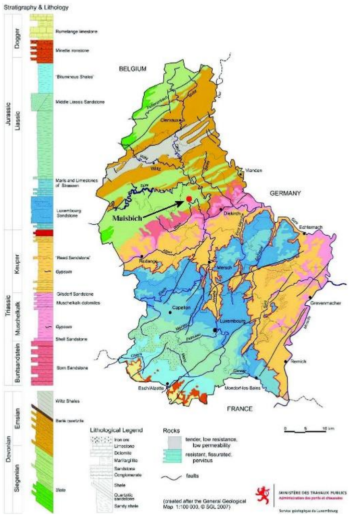
In order to obtain a sustainable water system, four regenerative goals have been identified for Luxembourg's water system. Reaching these goals should result in a water system that is able to absorb sudden shocks and be resilient over time.

1. Local (re)use of water:
Encourage the use of local sources to minimize over-extraction of certain sources and reduce the amount of energy required for transport.
2. Healthy groundwater recharge:
Stimulate the infiltration of runoff to recharge aquifers and mitigate the negative trend of increasing fast drainage due to more intense precipitation peaks and soil sealing.
3. Good water quality:
Reduce the negative anthropogenic influence on water quality and stimulate (natural) purification before infiltration or drainage.
4. Balanced extraction over the year:
Discourage excessive usage of water in summer and deploy more efficient irrigation methods for (future) food production.

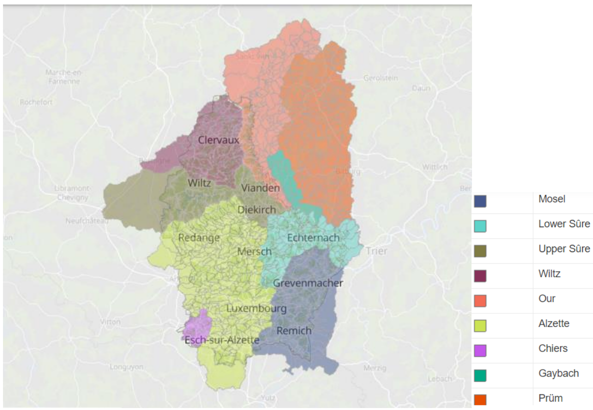
the gap in water

Note: the qualitative and quantitative assessment are still preliminary and based on rough estimations where data is unknown.
Luxembourg has a distinctive, split lithology. The northern part of Luxembourg, called Oesling, is characterized by hard rock formations, which allow for little infiltration of precipitation runoff. The southern part of Luxembourg, Gutland, contains softer rock formations which contain aquifers. The lithology and topography result in a number of different catchments within Luxembourg. Also, the different catchments, which cross borders with neighbouring countries.

Groundwater bodies in Luxembourg have a poor qualitative state due to eutrophication.
On an average yearly basis, there is a precipitation surplus of 250 mm, which equals 646.5 million m3/year over the entire area of Luxembourg. In order to translate this into runoff and groundwater recharge, Luxembourg's geology is simplified into a fast drained, impervious Oesling (hilly terrain), and a slow drained, more pervious Gutland (lowlands). As the impervious Oesling constitutes roughly 32% of Luxembourg, this area receives ~207 million m3/year. The remaining ~440 million m3/year falls on Gutland.

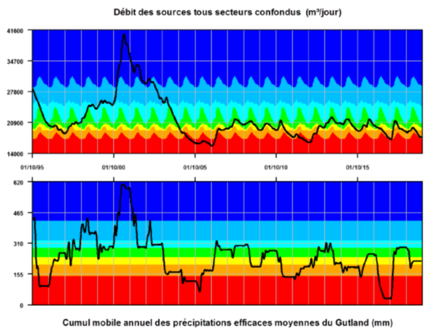


Lithology

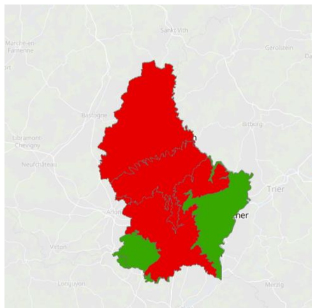


Cross border catchment

Given the soil properties of Oesling and Gutland, the estimated quantity of groundwater recharge is roughly 5% in Oesling, and 11% in Gutland. Most of the excess precipitation runs off overland and feeds the Esch-sur-Sûre reservoir. A large portion of the excess runoff is quickly drained by streams. Of the 440 million m3/year of precipitation surplus in Gutland, roughly 49 million m3/year infiltrates and recharges aquifers. These aquifers are large sources of water use in Gutland, with drinking water companies (26.8 million m3/year), industry (22 million m3/year) and agriculture (0.2 million m3/year) all laying claims on subsurface water reserves. In addition to the extracted 26.8 million m3/year, the drinking water industry uses 20.2 million m3/year from the Esch-sur-Sûre reservoir to supply urban areas. Figure ## shows the major water flows in Luxembourg, including the locations where CO2 is emitted in the water cycle.



Effective precipitation (precipitation minus evaporation) in Gutland

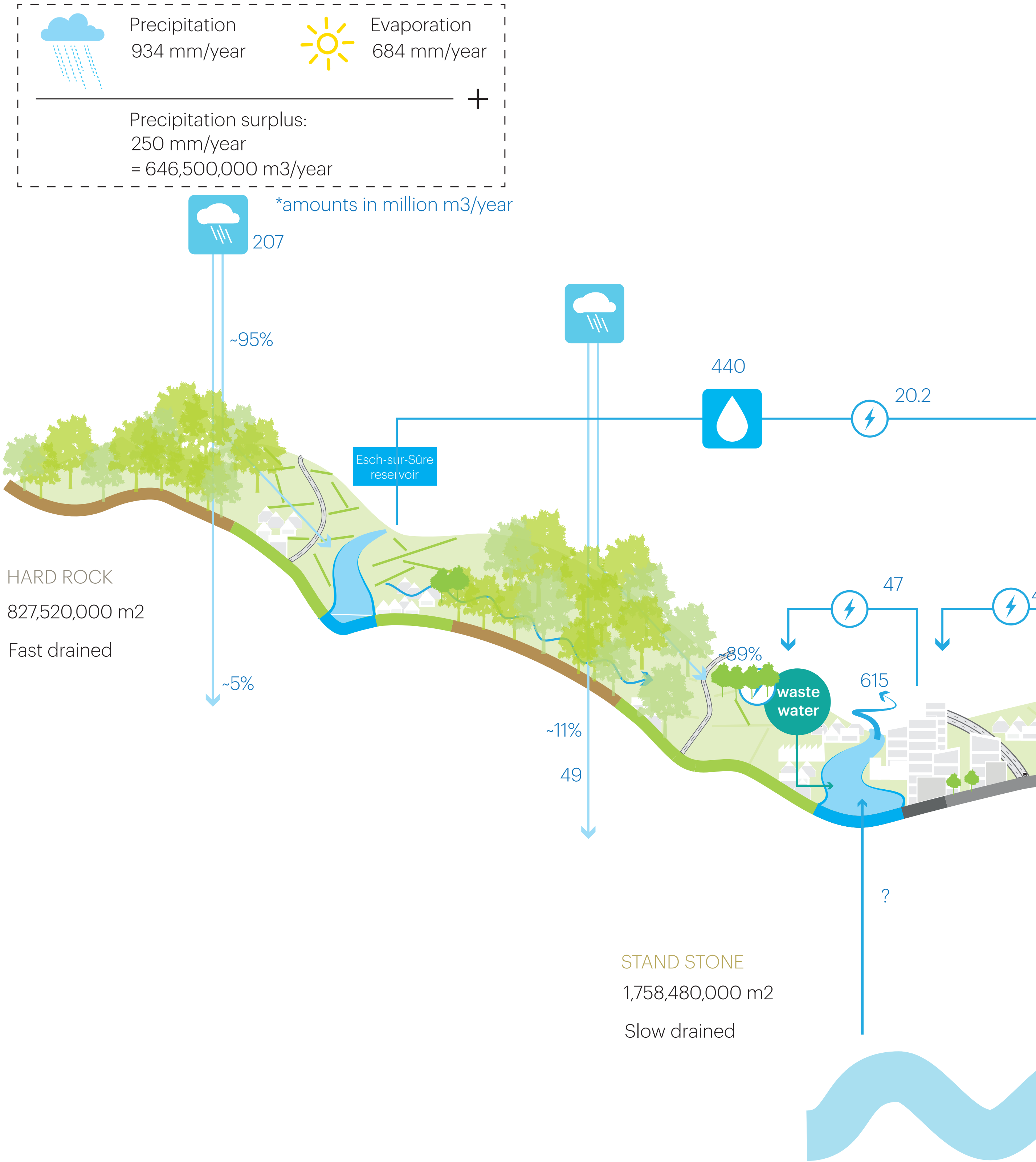


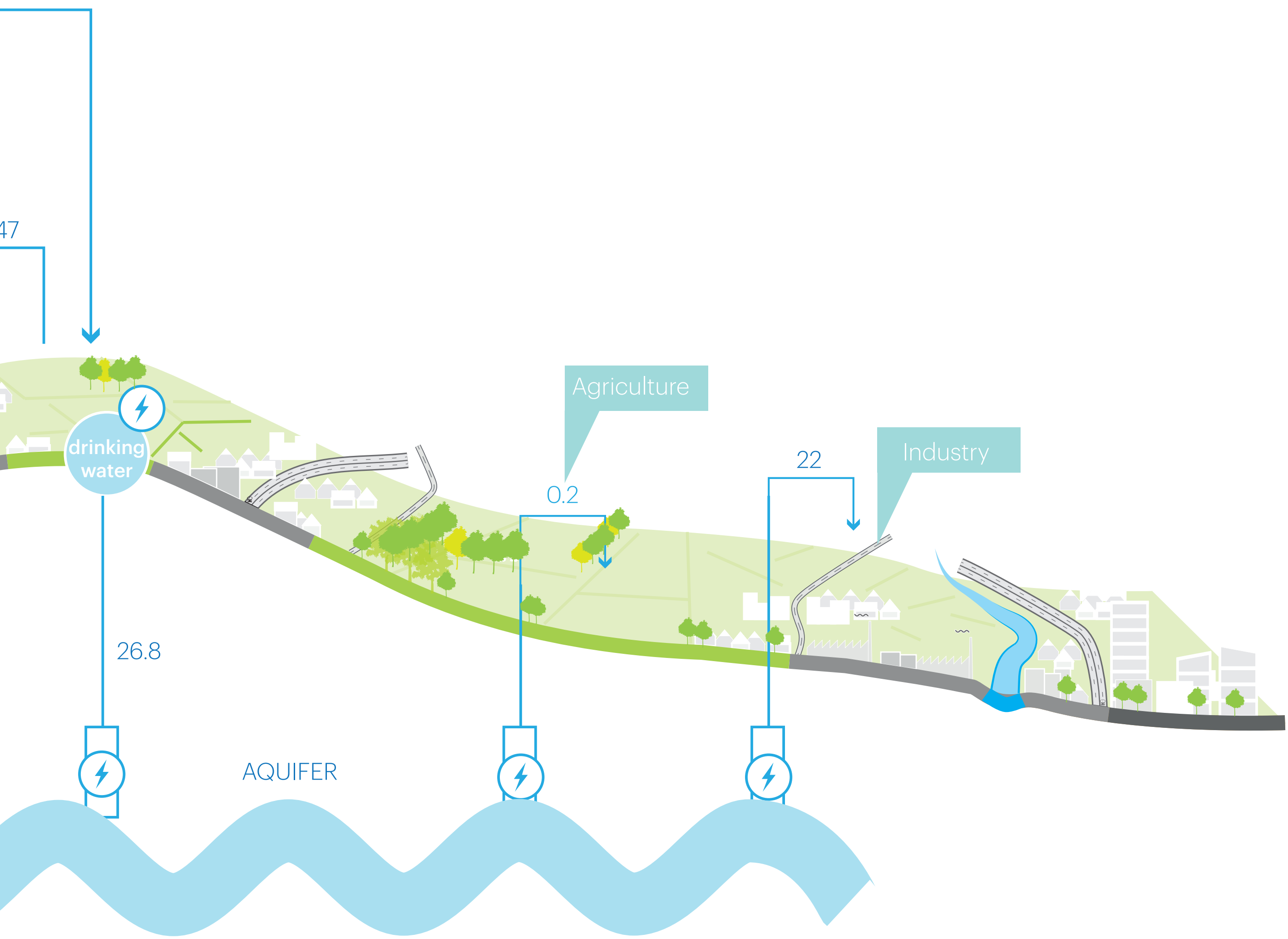
Quality of water bodies, poor in Luxembourg

the actions in water

Local (re)use of water:
•Create local buffering capacity near urban areas.
•Centralize waste water treatment.
•Reduce dependency on Esch-sur-Sûre reservoir.
Healthy groundwater recharge:
•Reduce soil sealing.
•Reduce fast drainage component.
•Maintain high groundwater table.
Good water quality:
•Prevent adversity of industry on water quality.
•Purify water before infiltration.
Balanced extraction over the year:
•Discourage water usage in summer.
•Reduce agricultural groundwater demand.

metrics and phasing




47
Agriculture
drinking water
0.2
22
Industry
26.8
AQUIFER

Mobility

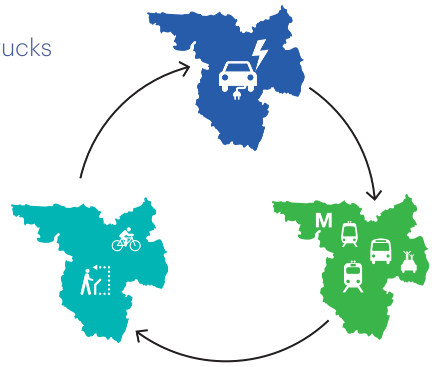
Mobility affects all aspects of society, such as vitality, quality of life, sustainability, social cohesion, social participation, and the efficient and effective use of government resources. We therefore go beyond CO2 effects which mobility has. Besides the potential of reducing CO2 emissions by new mobility, transforming mobility can have a positive effect on aspects like people's health, social inclusion, a greener urban environment for higher quality of life, a lower number of casualties to name just a few.

	01 TARGET	02 GAP	03 ACTIONS (TILES)				
	REGENERATIVE GOAL	GAP (low,high)		03 ACTIONS		Quantifications	Tools
A	LOCALIZED SYSTEM						
	TARGET: By 2050 a reduction of long motorized person and freight trips (>7,5km) of 25% and short motorized trips by 50%	**GAP: 78% of cross-border commuters going to Luxembourg; 5,5million CO2related to transport**	1.1	Reduce mobility trips			
		GAP: 31 traffic fatalities in 2018		Promote working from home	M1	#day people work from home	Internet facilities / Employers engagement
				Create localised system by walkable, cycleable city. (avoid)	M2	total distance travelled per person	Coordination of land use and traffic infrastructure: smart land use for reduction of trips and km (avoid and shift). Urban planning policies
				Promote shorter/less freight trips	M3	total freight kilometers travelled	CO2 tax for freight travel
				Promote E-services	M4	total distance travelled per person	Reduce trip to the city by offering more access to more service online (health care, education etc..)
				Promote short distance travel	M5	total distance travelled by car, total distanced travel by air	distance based road charging, tax air travel
			1.2	Attactive urban design			
				Reduce speed limits	M1	average speed on city roads	
				Street design	M2		
B	REGIONAL MULTIMODAL SYSTEM	GAP: 69% of trips is by Car					
	TARGET: By 2050 a modal shift from single occupancy vehi		2.1	Shift to more sustainable modes			
		GAP: 31 traffic fatalities in 2018		Promote walking and cycling	M1	#of trips by bike and walking	Improve cycling & walking facilities, livable streets, 15-minute neigborhood. Induce change of behaviour towards Active Mobility, Healthy Mobility.
				Disincentivize traditional car travel	M2	#of trips by car	Parking policies, Road diet, Lower speed limits
				Promote transit use	M3	#of trips by transit	Transit-Oriented-Development, High Frequency Network, High Quality hubs and first and last mile solutions
				Promote sustainable freight travel	M4	#of freight trips by train / ship	Intermodal hubs, toll freight travel by road
			2.2	Improve mulitmodal and share mobility			
				Improve transfer between modes	M1	#of multimodal trips	Multimodal hubs, single-transit-pass
				Stimulate shared mobility	M2	#of shared mobility	Mobility- as-a-service, bikeshare & carshare
C	CLEAN VEHICLES	GAP: 1.9% market share e	3.1	Shift to cleaner vehicles			
	TARGET: By 2050 all motorized vehicles will be powered by clean energy			Promote shift to cleaner cars	M1	# of zero emission cars on the road	Tax incentives, Charging infrastructure, Prohibit sales of combustion engine cars, national (environmental) policy: "100% clean vehicals by 2050". Zero emission zone.
				Promote shift to cleaner transit	M2	# of zero emission buses on the road	Prohibit use of combustion engine buses, invest in electric transit vehicles
				Promote shift to cleaner trucks	M3	# of zero emission trucks on the road	Zero-emission zone for trucks, CO2 taks for freight

	04 METRICS		05 INTEGRAT	06 GOVERNA	07 PHASING (SECTIONS)		
Scale	Positive outcome	Negative outcome	Mitigation (T	Priority	2030	2040	2050
Region					50%	75%	100%
Local (Urban)					25%	75%	100%
International					100%	100%	100%
Local (rural)	Reduce CO_2 emissions, improve health (active transportation, casualties & air quality), reduce noise, improve social cohesion, reduce run-off, reduce space need for roads, improve liveability villages and cities, improve local economic interaction, reduce energy use	Reduce global economic interaction, Reduce global / international travel by air and car and truck			75%	100%	100%
International					100%	100%	100%
Local					33%	66%	100%
Region					75%	100%	100%
Region					25%	75%	100%
International	Reduce CO_2 emissions, improve health (active transportation, casualties & air quality),reduce run-off 7 noise, reduce space need for roads, improves equity of the transport system, reduce energy use	Increased cost of driving			25%	75%	100%
Region					75%	100%	100%
Region					50%	75%	100%
			optional				
Region							
					25%	90%	100%
Region					100%	100%	100%
Region	Reduce CO_2-emissions, reduce energy use, reduce noise (only at low speed roads), clean long distance transport	does not improve equity, still need road space			25%	80%	100%

... towards a (re)generative mobility system

Cleaner vehicles
ZE emission cars, transit, trucks
Charing infrastructure



Localized system: Avoid trips & improve quality of life
Living streets & slower speeds
Proximity to services

Regional multimoda lsystem: Shift to sustainable modes
Hubs and Interchanges
Charging infrastructure

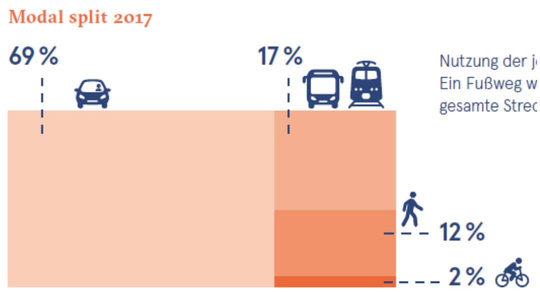
We look into how the transport and land-use system in Luxembourg can improve in a way so it will become

- more attractive (indicators: children walking to school, quality of public space);
- cleaner / more environment-friendly (indicators: use of sustainable modes, Zero emission, energy consumption, small particles);
- more inclusive (indicators: cost of travel, access to opportunities);
- safer and healthier (indicators: road accidents, air pollution, noise, use of active modes).

The current paradigm of improving transport systems has a strong focus on increasing capacity and increasing the speed. However, this focus does not contribute to the goals mentioned above. We must shift towards the goals as mentioned above. A key factor is accessibility, which can be achieved by making better connections for everyone and by improving proximity (bringing functions/amenities/opportunities closer).

the gap in mobility

The report “Modu 2.0: Strategie für eine nachhaltige Mobilität“ sets the direction towards more sustainable mobility. The mobility pattern with a high share of cars in the modal split makes it obvious that there is a big potential to exploi. The goals for 2025 aim for less motorised traffic and more public transport and active mobility (pedestrians and cyclists), with a special goal for walking to school, a decarbonisation of 40% by 2030 and a reduction of NOx-emissions by 2030 and zero casualties, amongst others.



the actions in mobility

Generally, we see the need to work at two scales. On the one hand at the regional level, and on the other hand at the local or street level. Mobility patterns are not bound by municipal/national borders. Thus, on top of working within the municipality/city boarders, a regional/cross-border scale is of great importance. On both scales, transport- and land use integration and multimodality must be improved. However, the strategies employed are different. On the (cross-border) regional scale, avoiding trips by allocating the functions in space in a smart way (jobs and amenities close to housing etc.), or making longer trips less often. For a large reduction in CO2, it is essential to avoid long-distance trips. For those trips which are hard to avoid, shifting from fossil-fuel based transport to (cross-border) public transport is necessary. On the municipality/city and neighbourhood scale, improving proximity and attractiveness, as well as promoting a slower city, a walkable and cyclable city are key strategies. This can be done on a street and neighbourhood level. Infrastructure changes slow, and it is easier to change a small residential street than to build up a regional (cross-border) public transport system. To achieve a regenerative mobility system, however, all actions must be taken.

Regarding the type of actions, we are looking for measures that not only reduce mobility-related emission, but also have an impact on our life environment in more general terms, by improving the quality of life in our cities at the same time.

Instead of wanting to move faster as we have done for the last centuries, we might want to aim to move slower. The growth in speed of transport systems has disconnected people, goods etc.. from their direct environment. We want to counteract this trend and achieve a healthier lifestyle and environment to live in. A focus on cleaner cars or vehicles does not help us to achieve a more regenerative mobility system, because a mobility system centred around the car still requires a lot of space, energy, resources and does not contribute enough to a healthier, more inclusive and attractive mobility system and living environment.

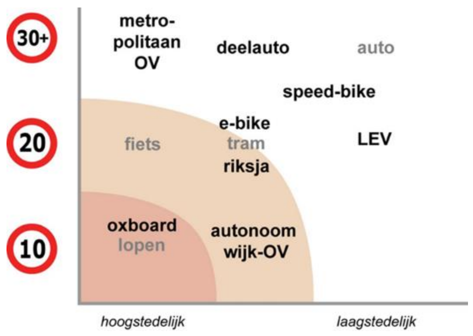
Approach "Avoid - Shift – Improve"
The approach A-S-I (Avoid/ Reduce, Shift/Maintain, Improve) seeks to achieve significant GHG emission reductions, reduced energy consumption, less congestion, with the final objective to create more liveable cities.

https://www.transformative-mobility.org/assets/publications/ASI_TUMI_SUTP_iNUA_No-9_April-2019.pdf

Mobility transition put in space
Urban
Localized system: Avoid trips & improve quality of life
Living streets & slower speeds. The walkable and cyclable city.
Proximity to services

Sub-urban / rural
Regional multimodal system: Shift to sustainable modes
Hubs & interchanges
Push and pull measures

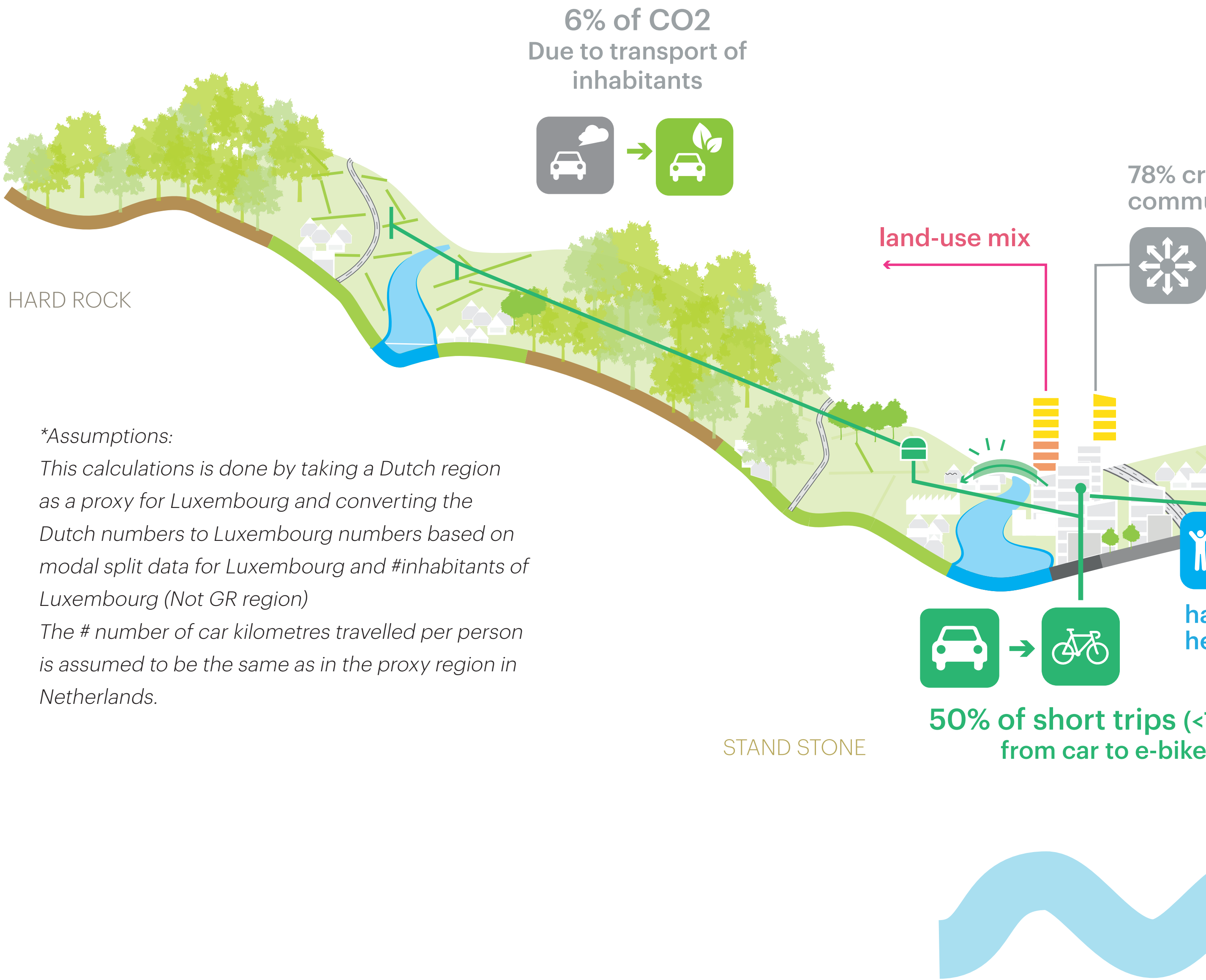
General
Cleaner vehicles
ZE emission cars, public transport and trucks
Charging infrastructure
Cleaner vehicles only do not not make the mobility system more sustainable and human, however



metrics and phasing

Action 1: Localized system, replacing 50% of short car trips (<7,5km) with bicycle trips in Luxembourg. Changing peoples' travel behaviour: use bicycle for short trips instead of car.
Metric 1: 6% CO_2 reduction in emissions caused by transport of inhabitants
0,38Mton CO_2 reduction per year*

By changing behaviour in mobility, you contribute to a regenerative system because you reduce unsustainable traffic due to a reduced number of car trips. Micro-climate is enhanced because of reduced CO_2 emission. Quality of urban environment is improved because of less traffic emissions (less noise, less air pollution, public space freed up due to fewer cars).
At the same time, by getting more people on bicycles, this improves health end reduces health costs due to more active mobility. Moreover, streets have the potential to become a space for social interaction instead of space to move through or park cars..

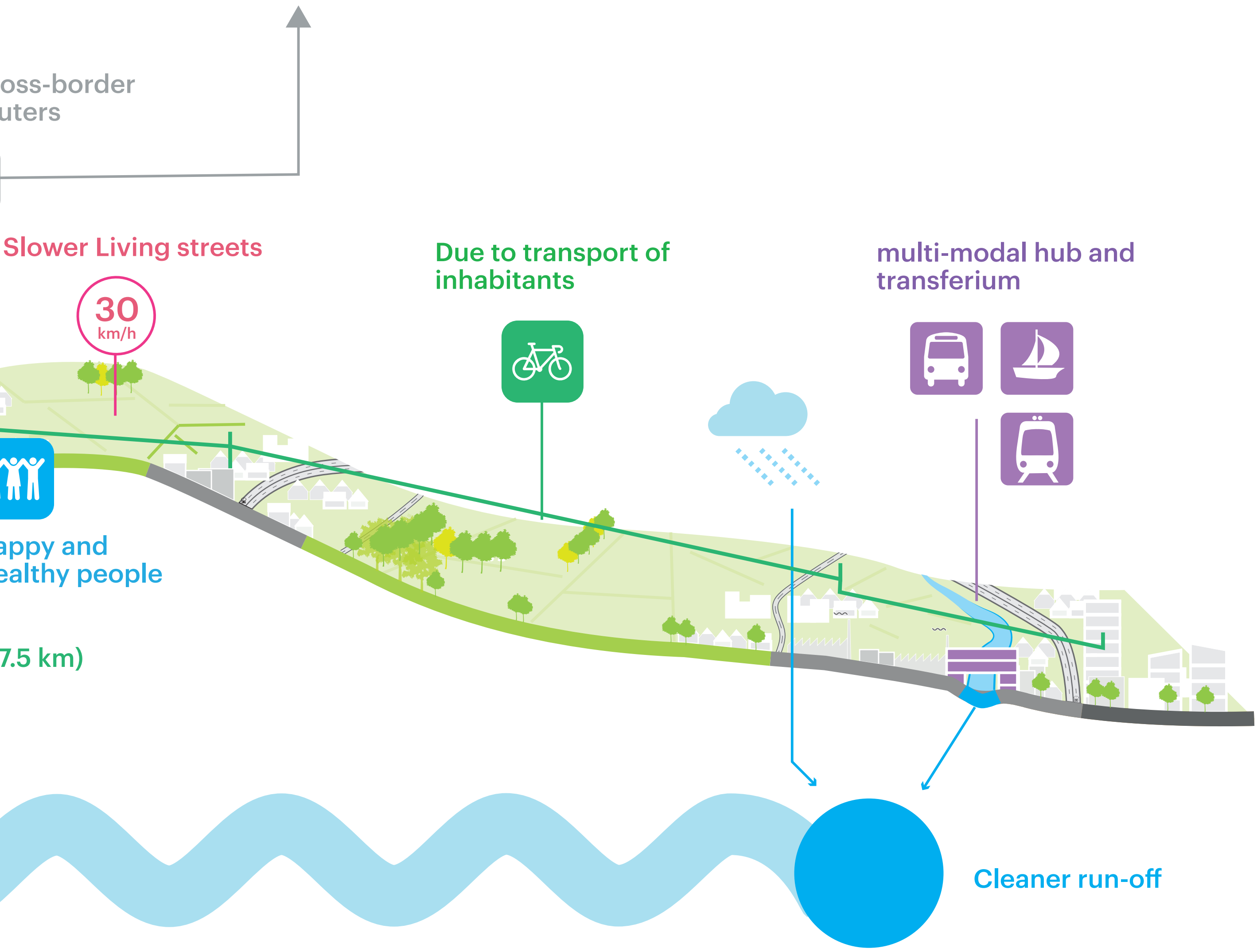


**Assumptions:*
This calculations is done by taking a Dutch region as a proxy for Luxembourg and converting the Dutch numbers to Luxembourg numbers based on modal split data for Luxembourg and #inhabitants of Luxembourg (Not GR region)
The # number of car kilometres travelled per person is assumed to be the same as in the proxy region in Netherlands.

Other realms/metrics than CO2 affected by this action: health (health costs), air quality (small particles, NOx-emissions), equity (accessible by higher numbers of lower-income people), safety (accidents, casualties).

Tools:
- Regional bike network (including e-bike)
- Living streets (car is guest, pedestrians and cyclists have priority)
- Lower speed limits / Road diet / parking policies
- Cycling education / Cycling promotion (employers)

Phasing gradually until 2050•
Changing streets (gradual over time), new development start at the beginning
- Transport and land-use integration (plan now effects later)
- Shift to electric (slowly accelerating)
- Making cars more expensive (start now)



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