LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Environnement, du Climat
et du Développement durable

UNIVERSITÉ DU LUXEMBOURG

NEXUS FUTURES Project Report

2017 - 2021

Final project report to the Ministry of the Environment, Climate and Sustainable Development

NEXUS FUTURES
Sustainable engagement with water and land

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The achievements and deliverables are described with reference to the research questions and deliverables of the research proposal that is part of the NEXUS FUTURES Convention (2017-2021).

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Executive summary

How can we learn to better safeguard and regenerate the earth's life support system, constituted of healthy water and soil systems and the interdependent web of diverse life forms, when our land use and socio-industrial emissions largely undermine their self-regenerating capacities? How can we overcome systemic challenges to such regenerative action in an age in which diverse human influences on environmental systems and processes are all pervasive and interconnected across local and global scales?

The five-year NEXUS FUTURES project explored approaches to participatory governance of water and land. The project served to identify systemic challenges, and to develop concepts, processes, methods and tools as basis for more concerted regenerative actions by individuals, groups, organisations and society at large. The project design started from the assumption that *what and how we know shapes how we think and act* as we engage with water and land. One central question therefore concerned how we can change knowledge production processes and what role science can play as basis for regenerative actions, acknowledging that our social and ecological systems co-constitute each other. A related question was how we can stimulate collaboration and co-creation of knowledge and science across disparate sectors (of government, expertise and professions, the economy and society) in a way that emergent knowledge is accessible, understood and acceptable to all as evidence-base for more concerted action.

Funding and commitments: The project was co-funded by the MECDD and the University of Luxembourg. The NEXUS FUTURES project is the first example of transformative sustainability research in Luxembourg. The research approach consisted of participatory action research and was carried out by the research group on social-ecological systems at the University of Luxembourg. Outcomes of such transformative research approaches in general terms that were listed as commitments in the 2016 Project Convention included new concepts to structure future-oriented dialogues across differences in interests and expertise, development and capacity building for new approaches to understanding and acting on complex social-ecological systems, changing relations and network effects, innovative tools, technologies, and sequel projects to leverage the achievements. The project had three interlinked research strands, outputs and outcomes of which are described below. An overview on all scientific deliverables is provided in Annex I.

Project governance: We worked with a reference group with 15 stakeholders engaged in water governance or farming at the local or national level, who were consulted on substantive and procedural choices throughout the projects' duration. The Scientific Advisory Board with four internationally leading experts provided advice on related international research, suitable methodologies and representations of the work.

1. What knowledge for more concerted action on water governance in Luxembourg?

The first research strand conducted in contribution to a doctoral dissertation by Kristina Hondrila asked **what knowledge serves action for sustainable water governance and social learning in two river partnerships**. First insights from empirical data on case studies of implementing water protection zones and river restoration/renaturation projects help to identify factors that help or hinder regenerative projects such as a river renaturation project at the Syr or the institution of additional water protection zone at the Upper Sure. Research design and methods included close to 60 narrative and walking interviews, three collaborative workshops, numerous site visits and observations and documentary review.

The research describes concrete implementation challenges of government measures largely arising from different understandings of issues and potential solutions by actors from different professions active at different levels of governance or in different sectors of government or society. The thesis provides a historical perspective on how these situations and misunderstandings across actor groups arose. This conceptual framing helped us to pin-point important barriers to local actions for improving water quality in two river partnerships and provide recommendations on how to overcome these (Hondrila, 2021). Regenerative initiatives, such as river restorations are always rooted in place-based implementation actions by motivated people, who feel and are empowered to act in an enabling policy, financial and social environment. Insights from the research highlight that regenerative initiatives require an in-depth understanding of local unique dynamics, diverse interests, and interactions between relevant factors across the ecological, social, personal and technological spheres. Design of such initiatives should also embrace salient uncertainties in relevant knowledge and the fact that futures are open and prone to disruptive events in turbulent times. Learning from actions and experimentation will benefit from networks across a range of spatial and temporal scales and levels of governance. In addition, taking human needs and wants in diverse local groups into account, as well as circumstances of people who lead the regenerative initiatives helps shaping a better understanding of local/regional interrelations. The findings as such can be seen to underline risks of focusing policy-making on promoting detailed measures in to the form of one-size-fits-all policy and market solutions; the research highlights merits of opening rooms for experimentation with place-based initiatives by actor groups supported with public funds that come with few or no strings attached. The work points to needs to improve learning across places in networks with the help of learning platforms.

Scientific deliverables include one Ph.D. Dissertation on knowledge for action in water governance in Luxembourg, contributions to two scientific papers, and three conference presentations. A related action research project Aktioun-Nohaltegkeet (link) in our group is also drawing on these insights to further improve a fit-for-purpose learning platform. A more detailed account of the research approach and insights are given in section 3 of this report.

2. Exploring the potential of citizen science for water governance

In the second research strand, Karl Pickar led the development of experiments with **citizen science on water quality** to explore whether it is possible to engage volunteers in collecting data on water quality and whether such data is acceptable to authorities and can complement official data in meaningful ways. The research points to advantages of a shift from informing policies and practical actions exclusively expert based to the co-creation of evidence and meaning making of it in participatory processes with the help of citizen science.

The work-strand on citizen science thus involved two large contributory data collection campaigns carried out in collaboration with the NGO Freshwater Watch, in which we engaged over 300 volunteers who sampled and assessed water quality across different water bodies in Luxembourg. Furthermore, we worked with one corporation some of whose staff engaged in more regular self-organised sampling activities on sites recommended by local experts from the river partnership Syr. Finally, we held three participatory co-design workshops to develop a citizen science tool with a systemic indicator set for a distributed approach to co-creating an evidence base for policy and local actions that directs attention to mutual influences in human-environment relationships (See Figure 0.1). The tool set is implemented in collaboration with Spotteron, who provides Citizen Science apps and data management as a service. The app will distinguish two different modes of data gathering: guided and structured visual observations by any volunteer or collecting quantitative data on water quality with test kits under the guidance of trained volunteers or staff from environmental organisations (e.g. for chemical substances such as nutrients). The observations include indicator species for ecosystem health as well as a visual survey of disturbance factors and easily visible structural parameters of stream impact models. Such observation campaigns can then potentially be implemented in all river partnerships to create a comparable mapping of the different river basins on a website. A simple didactically prepared toolkit for teachers and students and guided walks in nature parks and exhibitions will be developed as follow-up to the project.

Scientific deliverables include one scientific publication to date, two other papers that are in preparation and two invited to presentations at conferences of statisticians organized by EUROSTATs European Statistical Advisory Committee and the German Federal Statistical Office to explore the potential of citizen science to serve as data pool for official statistics. In sum, this systemic citizen science tool set offers a approach to institute a more distributed approach to co-create an evidence base for policy and local actions. A more detailed account is provided in section 2 of this report.

3. National scenarios on engagement with water and land in 2045

The third strand served to develop **national scenarios for anticipating potential future challenges and changes in ways of how we engage with water and soil in 2045**. This set of three scenarios provides a systemic understanding of how behavioural patterns for engaging with water and land arise from the interplay of different circumstances in society, the economy, technology and the state of the ecosphere. The set of descriptions of three different worlds is designed to provide common points of reference for workshop discussions with different stakeholders, that have a very different understanding of the world, what matters most and what might need to be changed first. The scenarios also highlight that an argument merely based on past personal experience and established scientific facts will be inadequate in the face of disruptive changes in turbulent times. The participatory process to develop the scenarios drew on all interviews conducted for the other two research, and a dedicated set of interviews and workshops. Furthermore, the research approach included work with diverse experts contributing quantitative and qualitative studies, exploring different aspects and implications of the three scenarios in more detail. First, a quantitative study by Dr Andrew Ferrone, the Luxembourg representative to the IPCC provides plausible modelled ranges for frequency of occurrence of extreme weather events and seasonal distributions of temperatures and rainfall that served as basis to differentiate the climatic conditions in the three scenarios. A second quantitative study concerned water demand and supply. This study suggests that water will become a primary constraining factor for population growth and economic development at the latest in 2030 in spite of inauguration of the new SEBES plant. Based on this modelling approach, three different scenarios for water use and sourcing systems have been developed. Experts in spatial planning started from the recommendations of the participatory national process to develop goals of the ‘Third Industrial Revolution’ to explore implications for land use. Contradictions in terms of multiple competing land uses on certain areas of the country were resolved into three scenarios with different underlying logics for spatial organisation.

As such, the scenario set offers a tool for policy makers, individuals, organisations or mixed stakeholder groups to switch from prediction and control-based management to embracing open futures, uncertainty, accelerating and disruptive change in deliberations on promising pathways and concerted action to regenerating a resilient life support system in Luxembourg. Trade-offs that can arise from placing primacy on growth and technological progress, regional autonomy and well-being, or ecosystem health become apparent through work with the scenario set.

Deliverables produced from this work strand include capacity building for scenario work in over four national workshops and working groups with national experts, contributions to a first advanced text book on sustainability science (two manuscripts for international peer reviewed publications are in preparation), two workshops in Luxembourg, and a video and project website with tools to effectively leverage the scenario set for thinking out of the box in future workshops with public and private sector organisations and civil society. A more detailed account is provided in section 4 of this report.

4. **Methods and capacity building**

During the NEXUS FUTURES Project we engaged in stakeholder analyses and developed methods for contradiction mapping from interviews with diverse stakeholders and workshops. We developed approaches in and for Luxembourg for collaborative conceptual systems mapping to identify promising action fields in the face of complex and dynamic problems in social-ecological systems, and for working with scenarios to embrace possible disruptive events, uncertainties and open futures. The main shared aim of all these methods is to foster dialogue across differences in expertise and interests to offer engaged participants the opportunity to reframe issues and challenges and to see them with new eyes, through multiple perspectives (a first step towards a transformative learning experience). Apart from presentations at scientific conferences, two Ph.D. theses were completed. So far one paper fully dedicated to a work strand in the NEXUS FUTURES project was published in an international peer reviewed journal (König et al., 2021). We have contributed to papers by colleagues on related research topics (Caniglia et al., 2020; Luederditz et al., 2019). For our projects we have further developed and leveraged collaborative conceptual systems mapping of complex social-ecological-technological systems (Newell and Proust, 2018) as well as scenario and visioning approaches (Ramirez and Wilkinson 2016) with other international research groups over the past five years. We are at present writing a set of five papers on the past five years of research, however the pandemic has slowed us down as we had to develop participatory approaches for virtual settings. The papers outline our contributions to fields of knowledge relating to complex social ecological systems with a focus on the water-land nexus, and the academic literature on futures and scenarios, and citizen science.

In sum, in this research project we developed cross-scale participatory processes that served to explore alternative and open futures for our engagement with water and land, as well as an original and systemic citizen science tool set for water governance. With these processes we are seeking to facilitate the emergence of *transformative governance approaches* in Luxembourg and beyond. We also seek to create spaces for participatory evaluation and reflection on relevant policies and initiatives. These are distributed decentralised governance processes that seek to engage with uncertain futures to steer action in the present. Both our scenario set and the citizen science tool kit have been co-created by collecting and considering salient local 'seeds of change' (how salient place-based, including social innovations may disrupt current prevailing structures, practices, and norms).

The encouraging outcomes of the citizen science project strengthened our resolve to dedicate the next 10 to 15 years to further facilitating the establishment of innovative structures and practices for evidence-based learning for the regeneration of the life support system through place-based actions and policies in cross-scale participatory processes including citizen science approaches. We will extend these activities internationally with our network of partners. The ministerial support for a five-year follow-up project on drought resilience with a citizen science-based early warning system has been secured.

Transferability and scalability of the research approach and insights gained: Whilst our research is at present firmly embedded in the setting of Luxembourg, it is carried out in an internationally networked manner, also thanks to the international experts on the project's scientific advisory boards. **The situation in Luxembourg proved an excellent case study** as the pressures on land are well pronounced and more visible than elsewhere as it has been the fast-growing EU country. The sustainability of the social welfare system depends on growing numbers of cross border workers and associated economic growth is given primacy over other objectives. Given the clear limits of the biophysical carrying capacity of the land and impossibility of pure reliance on a more networked resourcing approach in turbulent times, transformation on how we engage with life support systems is required. Luxembourg has only two levels of governance, national and municipal, and serves well to explore the following questions. This presents unique opportunities for a better understanding of cross-scale interactions in transformation processes, and current disconnections between sectoral organizational regimes and governance levels.

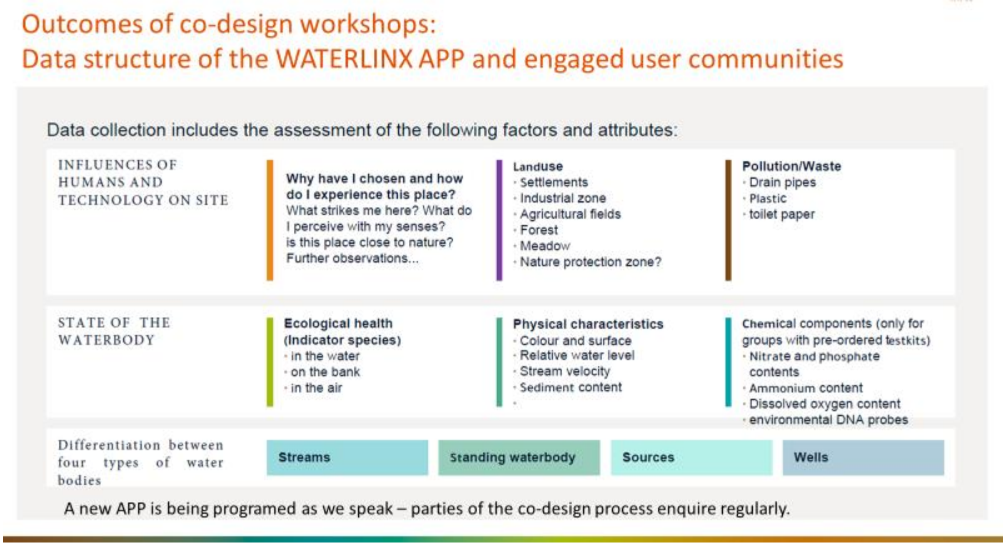


Figure 0.1 Outcomes of co-design workshops: Data structure of the WATERLINX APP

1. Introduction to the NEXUS FUTURES Project: Context and objectives

General research context and approach

Our planet's life support system, with healthy soil- and water cycle as basis for the co-existence of a web of diverse and interdependent life forms, faces increasing pressures from human changes in land cover and emissions from our socio-industrial metabolism (Diaz et al., 2019; Steffen et al., 2015). Potential impacts of climate change such as extreme weather events, and summer droughts in particular, will likely reinforce these dynamics. The interdependent acceleration of the loss of species, declining water quality, and land degradation across large regions on all continents, suggests that a mere focus on reducing human harm through targeted policy interventions in different sectors is no longer sufficient to safeguard life on earth as we know it. Regenerative actions are urgently required to safeguard the functions and enhance the resilience of life support systems to stress and shocks (Diaz et al., 2019).

This situation also applies to Western Europe, and Luxembourg in particular. As the EU country with the fastest resident population growth over the last three decades, and unusually high proportions of cross-border workers, the pressure on land and water resources is particularly high. None of one hundred examined (surface) water bodies was in good ecological status.[1] Competing industrial, agricultural, household, recreational uses, and pollution lead to progressive degradation and depletion.
There is a high level of vulnerability with respect to the national drinking water supply, as 70% of households rely on drinking water from one dam. This system has clear biophysical limits depending amongst other things on seasonal rain fall and proportions of run-off into rivers. This mandates diversification of sources for drinking water without jeopardizing local food production.[2] Recommendations of the High Council for Sustainable development therefore included that systemic reasons for degradation of water resources have to be taken into account in policy and practice. Analytic deliberation in multi-stakeholder processes informed by accessible monitoring programmes are required. A greater spatial and temporal coverage of sampling of surface and ground water will open new windows of accountability on compliance with the EU water framework directive. The quality of surface and ground water is deteriorating, whilst the numbers of drinking water sources have been declining. These considerations were also one basis for more recent legislation instituting a new approach to developing water protection zones.

With respect to terrestrial ecosystems, according to the national reporting in the frame of the EU habitat directive, about two thirds of all habitats investigated were in inadequate condition.[3] Recorded levels of species extinctions and threatened species are rising, especially among bird and bat species. Associated challenges in agricultural systems which in turn also impact the resilience of such production systems in the face of risks from climate change unfavourably include that after over thirty years of promoting land consolidation the number of structural elements in agricultural landscapes are greatly reduced. The sector has undergone intensification becoming ever more dependent on pesticide use and fertilization Prices for these inputs are however forecast to rise drastically, as well as coming under ever-more scrutiny from more stringent environmental regulations. There is little resilience for turbulent times of accelerating change and risks from climate change pointed out in the national strategy and action plan on adaptation to climate change.[4]

[1] Entwurf des dritten Bewirtschaftungsplans für die luxemburgischen Anteile an den Internationalen Flussgebietseinheiten Rhein und Maas (2021-2027) gemäss der Umsetzung der Wasserrahmenrichtlinie 2000/60/EG.
[2] Avis du Conseil Supérieure pour un Développement Durable sur l'Eau du 30.10.2014.
[3] Nationaler Bericht gemäss der Europäischen Naturschutz-Richtlinie (2013-2018).
[4] Strategie und Aktionsplan für die Anpassung an den Klimawandel in Luxemburg 2018-2023.

At the same time, our social – and knowledge systems are also becoming increasingly unstable (Maggs and Robinson, 2016). The acceleration of technological advances can also be disruptive, and further enhance inequity and distributional disparities. As societies within and across national boundaries or regional blocks become increasingly plural in terms of cultures and interest groups, social coordination for place-based action and for initiatives that aim for systemic transformations across governance levels or spatial scales becomes ever-more challenging. Furthermore, an increasing number of scholars reveal in their research to what extent patterns of behaviour linked with affluence and rigid power structures can act as barriers to such transformations (Wiedemann et al., 2020). Stresses on ecosystems and on society can influence and exasperate each other, as in the case of zoonoses-based pandemics. Thirty years of research on what sustainable management of natural resources takes, that are limited in supply but that no one can be excluded from access to, has shown: Traditional modes of social coordination including government regulation and market forces are less effective for the purpose of management of common pool resources such as water and fertile top soil (Ostrom, 2009). Governance should be more decentralized or 'polycentric', to cope with place-based complexities, and based on social learning with a co-created evidence base that is understood and trusted by all local stakeholders, instead of top down command control mechanisms. Ostrom was the first woman to be awarded the Nobel Prize in economics in 2009 for her work.

Relevant to evidence-based governance is also the consideration that science, if considered a 'social institution', faces unprecedented challenges: Education in the disciplines from secondary school to university and persisting career incentives and reward systems for researchers further drive the fragmentation of knowledge. To engage in research paradigms that produce universally applicable models reduces complexity, uncertainty, value pluralism in society. This is further reinforced usually by gate keepers in peer review and review of research proposals. Moreover, prevailing quality criteria and 'values and norms held to be binding to the man of science' date from just after WWII and have not evolved with the times: universalism, communism disinterestedness, organized scepticism in several ways fall short and can be counterproductive in a situation that science for governance sees itself often confronted with, when facts are uncertain, stakes are high, values in dispute. On top of these come structural challenges to contemporary science that include: Loss of credibility with lay public due to contradictions between fields; the internal replicability crisis; and occasional evidence of manipulation of science by vested interests.

Overarching research questions of the social ecological systems research group

Accordingly, my team's research is concerned with the interplay of science, policy, and practice for the regeneration of the planet's life support system, including healthy water, soil, and webs of interdependent life forms. We conceive humanity's existential challenges in the 21st century as emergent phenomena in complex social-ecological-technological systems. Our research approach, 'transformative sustainability science', relies on participatory processes to combine scientific knowledge and expertise from the natural and social sciences with place-based knowledge and experiences (König, 2018). The overarching research questions we have been addressing in diverse contexts are:

- What mechanisms for social coordination shall we focus on developing in support of a rapid transformation of how we engage as a society with our land's life support system? (What are the underlying conceptions of human agency, individual and collective rights, and responsibilities, and free will?)
- How can we organize scientific inquiry for better considering complexity, contingency, contradictions, uncertainty, and open futures? What evidence-base can serve to enable and

evaluate relevant policies in pluralist societies as well as meaningfully inform local regenerative actions?

- What scientific evidence base and understanding of science (in terms of its role in society and associated 'ontologies') can best inform distributed diverse local regenerative actions and approaches, and help us to learn from each other in a networked manner, considering different situations across places and time?
- What may be useful conceptions of science, knowledge, and quality criteria for their legitimation to support this?

Towards this goal our research is concerned with concepts, methods, processes, and spaces for collaborative scientific inquiry and future-oriented systems thinking in just transformation processes required for scaling up regenerative initiatives for water, soil and the web of life, and nature-based approaches for meeting human needs and wants.

Since 2021, this research focus is mirrored in central themes of the EU and national research priorities relating to sustainability, climate change and the Green Deal. Whilst transdisciplinary research still does not fit the prevailing quality criteria for science across all organizations engaged in public research or the funding thereof, in particular at EU level, such as in the more recent Horizon Europe calls for mission-drive research, transdisciplinary research approaches including the setting up of living laboratories and citizen science projects are increasingly sought after. We are particularly thankful for the public funds from the MECDD and the AGE that allowed to establish transformative sustainability science as participatory process with diverse stakeholders in Luxembourg.

Commitments made in the Convention of the NEXUS FUTURES Project (2017-2021)

The NEXUS FUTURES project (2017-2021) presents the first example of transformative research on social-ecological systems in Luxembourg. **The NEXUS FUTURES project aimed** to better understand and contribute to improving governance for the protection and regeneration of renewable resources such as water and soil. The project had three interlinked research strands:

1. **What knowledge serves action for sustainable water governance and social learning in two river catchments**

The first research strand asked. First insights from empirical data on case studies of implementing water protection zones and river renaturation projects help to describe concrete implementation challenges largely arising from different understandings of issues and potential solutions by actors active at different levels or in different sectors in multi-level governance systems. This conceptual framing helped to pin-point important barriers to local actions for improving water quality in two river partnerships and provide recommendations on how to overcome these (Hondrila, 2021). (See Section 3 of this report).

2. **Exploring the potential of citizen science to contribute to water governance**

In the second research strand, Karl Pickar explored suitable evidence bases for more decentralized approaches to water governance. Experiments with **citizen science on water quality** were developed to address question such as whether it is possible to engage volunteers in an *ad hoc* manner in collecting data on water quality and whether such data is acceptable to authorities and can complement official data in meaningful ways. The research suggests advantages of a shift from informing policies and practical actions exclusively expert based evidence to the co-creation of evidence and meaning making of it in participatory processes with the help of citizen science. (See Section 2 of this report).

3. **National scenarios for our engagement with water and land in 2045**

The third strand served to develop **national scenarios for anticipating potential future challenges and changes in ways of how we engage with water and soil in 2045**. This scenario set of future engagements with water and land is designed to provide points of reference for workshop discussions that help to make different understandings of the world and how behavioral patterns are produced explicit, and to invite reflection about one's own understanding in relation to that of others. The scenario set offers a tool for policy makers, organizations or mixed stakeholder groups to define future – oriented action fields and initiatives by switching from (short-term) prediction and control-based management to embracing open futures, uncertainty, accelerating and disruptive change. A more detailed account of this research strand is provided in section 4 of this report.

The Convention to finance the NEXUSU FUTURES project was signed on 16 December 2016 by the Minister of the Environment Ms. Carole Dieschbourg and the Vice Rector for Academic Affairs Prof. Dr Ludwig Neyses. A detailed account of the management of the budget was already submitted to the Ministry in April 2022. The main objectives and deliverables stated in the project description that is part of the Convention are listed in Figures 1.1 and 1.2. below. Text extracts with details on the research context as seen in 2016, the committed deliverables and research questions and hypotheses from the project proposal of the Convention can be found in Annex lll.,

The project was co-financed by the Ministry for the Environment, Climate and Sustainable Development and the University of Luxembourg. In terms of salaries, the project provided for one post-doctoral researcher, and one Ph.D. researcher Kristina Hondrila (contractual start March 2017 Ph.D. defense December 2020), and a full-time student assistant. The university financed an additional Ph.D. researcher, Karl Pickar, who was also part of the NEXUS FUTURES project team through an associated internal grant for interdisciplinary research projects (contractual start in July 2017 with budget from the WATGOV project 2017-2021, Defense on 16 December 2021), who conducted research on citizen science. The post-doc position originally called for someone with expertise in (socio-)hydrological modelling, after the second call we decided to hire someone with expertise in systems thinking, Dr. Isabel Sebastian, whose qualifications and language skills did however prove not sufficiently well matched for effectively contributing to transformative science relating to water governance in Luxembourg. We finally found a suitable expert, Dr. Jacek Stankiewicz only for a contractual start in March 2020.

The project governance was implemented as planned.

We worked with a reference group with about 15 local and national stakeholders as members, who are consulted on content- and procedural choices, as well as whom to invite as participants and experts in regular meetings throughout the project's duration.

The Scientific Advisory Board met twice to provide advice on salient cutting-edge theory and methods, and to develop quality criteria and a quality control process for these transdisciplinary projects that value place-based knowledge as well as academic concepts and methods.

The NEXUS FUTURES project has a scientific advisory board with the following members:

- Prof. John Robinson, Human Geography -Sustainability, Presidential Advisor on Climate Change at the University of Toronto, Canada, former Co-Chair of the International Panel on Climate Change Working Group 3 on adaptation and mitigation (accepted a Nobel Prize on behalf of the work of this group), advises on collaborative research with systems and scenario approaches.
- Prof. Muki Haklay, Geography and GIS, University College London, Head of the Research Group on Extreme Citizen Science, advises on co-design for citizen science for community building.
- Mr Walter Radermacher, Environmental Economist, Former Director General of EUROSTAT advises on the development of 'scalable' indicators for citizen science.

- Dr Jerome Ravetz, Philosophy of Science, Associate Fellow, University of Oxford, Saïd Business School, James Martin Institute on Science in Society.
- Mr Ciarán McGinley, NormannPartners, Expert on Knowledge Futures and Engineering (former chef de cabinet European Patent Office) advises on participatory scenario work and visioning.

Connection to teaching: There is a strong and strategically important connection between content, processes and participants in the Certificate in Sustainable Development and Social Innovation and the NEXUS FUTURES Project. The study program has to date and promises in future to provide an excellent pool of highly engaged and motivated candidates for research positions in our team (e.g. Ph.D. researcher Kristina Hondrila), and partners who collaborate with us as stakeholders in our projects. The Project was also used as a case study of transformative sustainability science in contributions to study programs at the Université de Namur, the University of Trier, the University of Hokkaido in Japan and the Sophia University in Tokyo. Furthermore, my ties to leading universities allow my team members to engage in collaborations with leading experts internationally.

Scientific deliverables: Annex I presents a full overview on all deliverables, scientific and practical. Apart from presentations at scientific conferences, two Ph.D. theses were completed. So far one paper fully dedicated to a work strand in the NEXUS FUTURES project was published in an international peer reviewed journal (König et al., 2021). We are at present writing a set of five papers on the past five years of research, however the pandemic has slowed us down as we had to develop participatory approaches for virtual settings. The papers outline our contributions to fields of knowledge relating to complex social ecological systems with a focus on the water-land nexus, and the academic literature on futures and scenarios, and citizen science. We have contributed to papers by colleagues on related research topics (Caniglia et al., 2020; Luederditz et al., 2019). For our projects we have further developed and leveraged collaborative conceptual systems mapping of complex social-ecological-technological systems (Newell and Proust, 2018) as well as scenario and visioning approaches (Ramirez and Wilkinson 2016) with other international research groups over the past five years. We were invited to present our research exploring on how citizen science might meaningfully contribute and complement official data, and may produce a data pool that can serve to develop official statistics, indicators and environmental accounts at two conferences organised by and for official statisticians at the national level (by the German Das Statistische Bundesamt) and at the EU level (by the European Statistical Advisory Committee and EUROSTAT).

The two doctoral candidates had to leave the University after completing their Ph.D.'s after nearly five years in the team (ceiling of time-limited contracts at the university) and deep immersion in our complex topics; this has left a gap in the team. However, in our view, as in major other societal transformation in history, quoting Mahatma Ghandi, 'the path' (including interviews, data collection campaigns and workshops as spaces for reflection and evaluation across differences in our case) 'is the goal', or at least a major aspect of it. They continue collaboration in other roles in Luxembourg (as director of an environmental NGO and as manager in a Nature Parc), as such our networked approach is now anchored even more strongly in practice.

Transferability and scalability of the research approach and insights gained: Whilst our research is at present firmly embedded in the setting of Luxembourg, it is carried out in an internationally networked manner, also thanks to the international experts on the project's scientific advisory boards. **The situation in Luxembourg proved an excellent case study** as the pressures on land are well pronounced and more visible than elsewhere as it has been the fast-growing EU country, the sustainability of the social welfare system depends on growing numbers of cross border workers and associated economic growth is given primacy over other objectives. Given the clear limits of the biophysical carrying capacity of the land and impossibility of pure reliance on a more networked resourcing approach in turbulent times, transformation on how we engage with life support system soil, water and web of life is required. Luxembourg has only two governance levels, national and municipal, and serves well to explore the following questions. This presents unique opportunities to better understand cross-scale interactions in transformation processes, and current disconnects between sectoral organizational regimes and governance levels.

The remainder of this report will present more detailed accounts of the research in the setting of the river basins by Kristina Hondrila, on citizen science by Karl Pickar, and on the scenario process.

Figure 1.1 Stated objectives

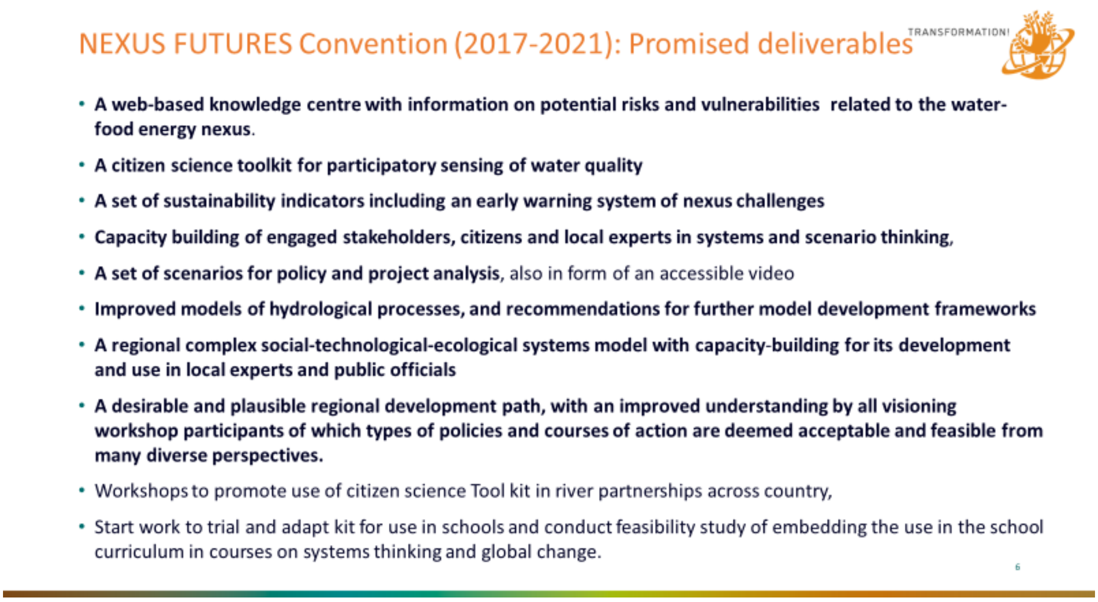


Figure 1.2 Promised deliverables

Before considering each research strand in detail in the subsequent sections of this report, let us first look at three common conceptions of governance and transformations in complex social-ecological systems.

Conceptual underpinnings: Transformation in complex social ecological systems

Our action research projects are unique in their combination of purposes, conceptual underpinnings from different knowledge fields and the methods deployed. The conceptual frameworks and tools we develop to guide collaborative scientific inquiry with stakeholders seek inspiration from three different schools of thought regarding transformations for sustainability and in particular the portrayal of cross-scale interactions in transformation processes. These three knowledge fields rarely cross reference each other but offer complementary perspectives as they each have a different set of 'blind spots'. Socio-technical transitions theory (e.g. Geels, 2018) has loosely inspired the conceptual distinction between niche experiments or seeds, and regimes and macro-level events / slow dynamics whose tensions and contradictions can destabilize regime-level dynamics. Whilst useful, the theory is inadequate for our stated purposes as largely supply-driven narratives are linear in nature and make blind to feedback effects and may not leave sufficient room for paradigm shifts at different levels of organization in social ecological systems, for example to overarching goals of such systems and groups of actors (e.g. economic growth).

In Panarchy theory (e.g. Gunderson and Holling 2002), transformation is defined as a 'shift to a new alternative system (or regime) with alternative processes and structures through human agency that is accompanied by shifts in the way authority, power and resources are structured and flow in social systems'. Fundamental changes in relations between people and their environments (Moore and Milkoreit, 2020) should be considered, as it is such system configurations that caused many of today's problems in the first place. How transformations might be scaled and connected across countries and continents is also of concern. Last but not least, we draw on Science and Technology Studies-derived conceptions such as socio-technical imaginaries that direct attention to the links between knowledge systems, science, technology and power structures. This can help to recognize distributional issues and reasons for resistance that present potential barriers to change (Jasanoff, 2015).

Regenerative initiatives, such as river restoration, renaturation or agroforestry projects designed for the purpose of flood control, will be rooted in place-based implementation actions by highly motivated people, who are empowered to act in an enabling financial and policy environment. This requires an in-depth understanding of local unique dynamics, diverse interests, and interactions between relevant factors across the ecological, social, personal, and technological spheres. Ideally, the design of actions and initiatives therefore takes account of complex interdependencies between changes across these spheres, and across a wide range of spatial and temporal scales (Garmestani et al., 2020). Design should also be informed by recognition of salient uncertainties and the fact that futures are open. Learning from actions and experimentation will benefit from being networked across a range of spatial and temporal scales and levels of governance, and take account of human needs and wants in diverse local groups, as well as circumstances of people who lead initiatives.

In our research projects we thus developed cross-scale participatory processes that served to explore alternative and open futures for our engagement with water and land. With these processes we are seeking to facilitate the emergence of *transformative governance approaches* in Luxembourg and beyond. We also seek to create spaces for participatory evaluation and reflection on relevant policies and initiatives. These are distributed decentralized governance processes that seek to engage with uncertain futures to steer action in the present (Chaffin et al., 2016). Both our scenario set and the citizen science tool kit have been co-created by collecting and considering salient local 'seeds of change' (how salient place-based, including social innovations may disrupt current prevailing structures, practices, and norms) (Rausepp-Hearne et al., 2020 and Perreira et al., 2021). Furthermore, our transdisciplinary and participatory research approaches are designed to make explicit diverse commitments to the future in mixed groups and inviting all to reflect about their own commitments in comparison to those of others embracing pluralism in society.

2. 'Exploring the potential of citizen science for adaptive water governance'

By Karl Pickar, Jacek Stankiewicz and Ariane König

Summary of the project and its results

Regenerative initiatives should take account of complex interdependencies between changes across social and environmental spheres, and across a wider range of spatial and temporal scales (Garmestani et al., 2020). Actions and experimentation will thus benefit from being networked across a range of spatial and temporal scales and levels of governance; at the same time, they should take account of changes in different place-based circumstances and human needs and wants in diverse local groups.

Accordingly, the citizen science work strand is concerned with the interplay of science, policy and practice for the protection and regeneration of surface water bodies. The decline of water quality is conceived as emergent phenomenon in complex social-ecological-technological systems. Our research approach, 'transformative sustainability science', relies on participatory processes to combine scientific knowledge and expertise from the natural and social sciences with place-based knowledge and experiences (König, 2018). We develop concepts, methods, processes, and spaces for participatory scientific inquiry such that they can embrace complexity, contingency, uncertainty and contradictions between diverse experts and interest groups. Citizen science, defined as a process of scientific inquiry to which volunteers contribute as well as expert scientists, presents a promising approach to engage diverse groups across different places, governance levels and across time, in collaborative processes to better understand and enhance our action repertoire to reverse environmental degradation, including declining water quality. The project responds to calls for greater citizen participation in water governance of the EU water framework directive, the CSDD expert opinion on sustainable water governance, as well as Vision 2020 of the European Statistical System for the generation of data and statistics from more diversified sources.

This part of the project presented my team with a first opportunity to engage in developing citizen science approaches for Luxembourg, and beyond. We could engage an internationally leading scientist Prof. Muki Haklay from the University College London as a member of the Committee d'Encadrement de Thèse of the doctoral researcher, and in capacity building efforts in environmental citizen science in Luxembourg. Karl Pickar successfully defended his Dissertation on 16.12.2021, accepted a job as manager in the 'Natur Park Our' in January 2022, with a continued interest in citizen science and collaboration. The final revised version of the Ph.D. Dissertation is to be submitted in due course.

The research project served to explore the potential of citizen science as a non-traditional source of data to complement the current data production process for evidence-based policymaking. Conceptual frameworks helped to explore the official data production process in relation to different purposes of environmental policies. These frameworks highlight different challenges that the current official data production process sees itself confronted with in relation to the different purposes of the policies and associated monitoring regimes. The empirical evidence from interviews, workshops and public data collection campaigns demonstrates that citizen science can meaningfully contribute both to the evidence base for policy and practice, as well as to an improved governance process.

Citizen science can be practiced in different ways that attribute different roles in the scientific inquiry process to scientific experts and non-expert citizen volunteers (Figure 2.1). The role of volunteers ranges from mere crowd sourcing of data points in contributory approaches to the co-creation of data sets and social processes for their analysis and interpretation in which citizen science stakeholders jointly define the purpose, research questions, and co-design the citizen science tool sets.

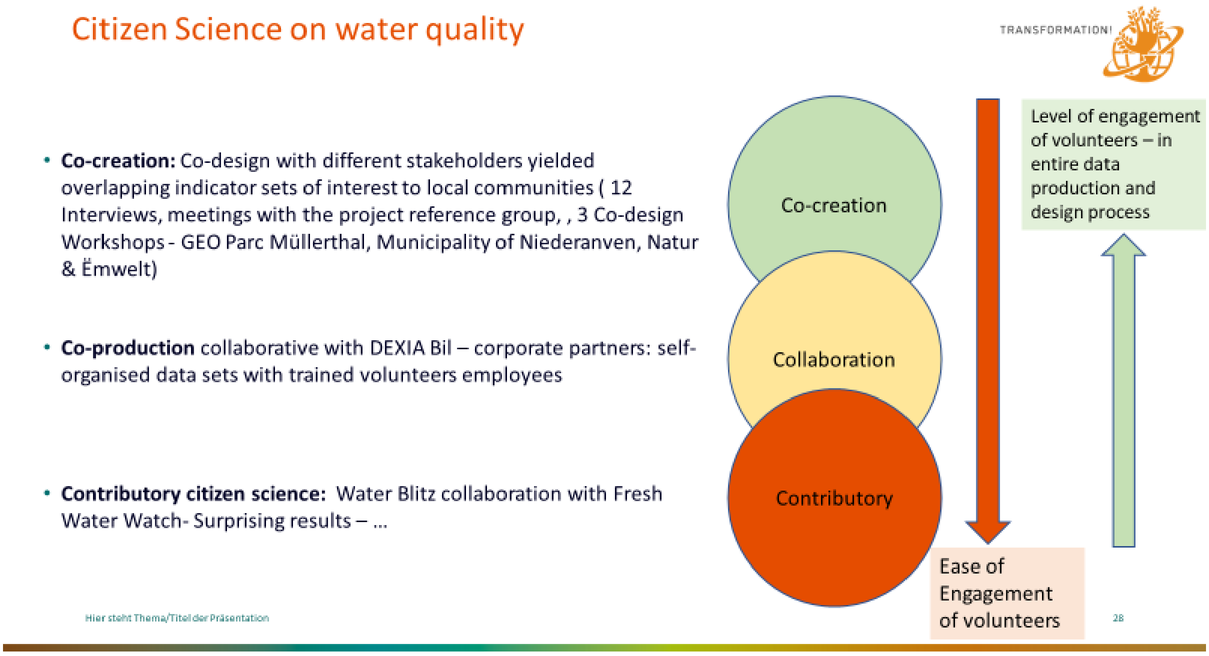


Figure 2.1 Citizen science on water quality.

Co-design of a citizen science tool for improved water governance with stakeholders

The project served to co-design *a citizen science approach with tools* including a detection kit, sets of indicators for different types of water bodies, a prototype mobile application with decision trees to determine data input possibilities (e.g., sets of site-specific or behavioural data including photos and other observations), which respond to quality criteria from diverse stakeholders and citizen volunteers for the co-creation of actionable knowledge. The co-design process engaged stakeholders from relevant administrations, municipalities, a nature parc and environmental NGOs in four workshops; engaged organisations are interested in continuing collaboration to deploy the tool once it is launched. The process helped to better understand and compare quality and design criteria for tools, processes, and spaces (virtual, institutional, social) for citizen science by diverse stakeholders including experts and lay persons, in diverse settings. The programming of the corresponding API and data base is expected to be completed by July 2022. Figure 2 depicts the data structure of the resulting citizen science tool kit.

These activities helped establish a network of engaged organisations for further work on citizen science and the decentralization of environmental governance. Working with these experts in turn also helps to legitimate to our findings and methods, and to increase chances that they gain traction in practice. Last but not least, partnerships with public bodies and active involvement in advisory committees, and our interactive research style aiming at dialogic learning by all engaged in interviews and workshops, contribute to capacity building relating to citizen science for decentralized or ‘polycentric’ water governance in practice with professionals.

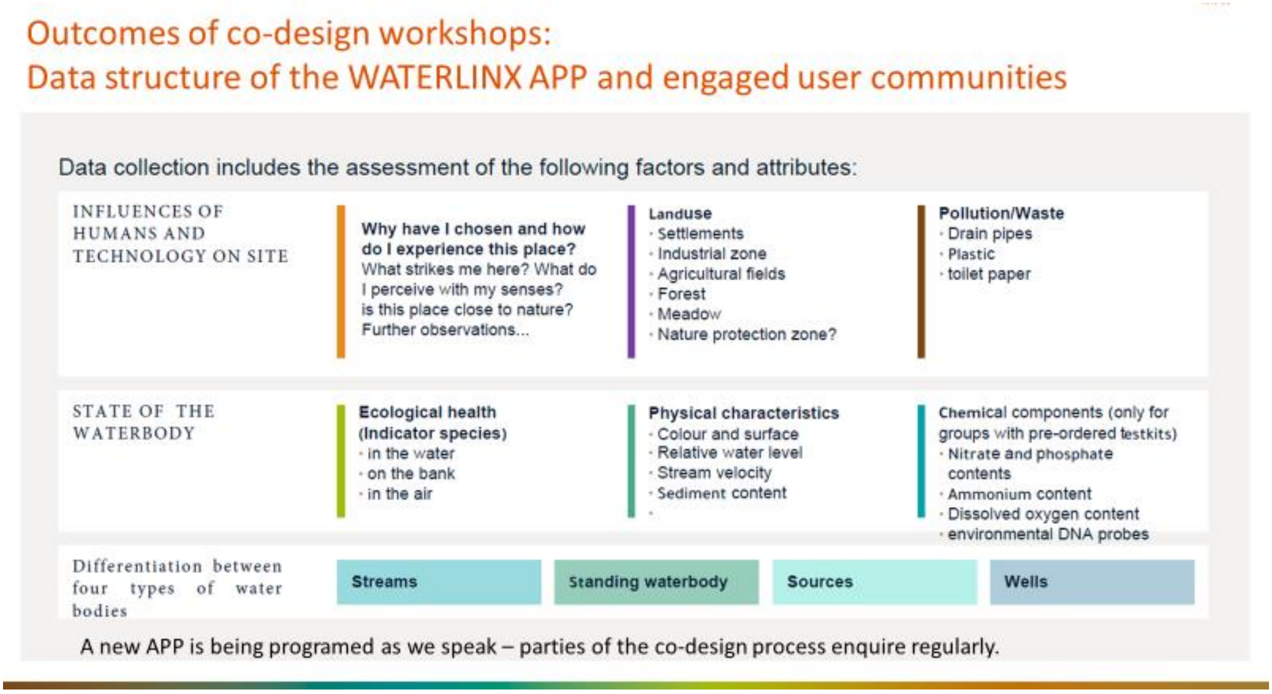


Figure 2.2 Outcomes of co-design workshops: Data structure of the WATERLINX APP

The co-design process resulted in unique sets of indicators that are deemed appropriate for citizen science for adaptive governance in Luxembourg (see e.g. the WATGOV Working Paper 1 by Pickar & König, 2020). From this co-design process we learnt that our initial focus on indicators such as nutrient levels was of interest (nitrate and phosphate content, high levels of which cause eutrophication, a process that undermines species diversity in aquatic habitats). The collaboration with Prof. Jo Hansen at the FSTC allowed to refine some of the indicators on physico-chemical properties (e.g., dissolved oxygen and ammonia levels in surface water) that are suitable for use in citizen science. However, in response to suggestions at the workshops, the original plan to develop a test kit for pathogenic bacteria was replaced with the development of a set of indicator species for the state of health of diverse types of aquatic ecosystems. This part of the project involved close collaboration with Luxemburg's experts on aquatic ecosystems in different types for water bodies from the water management administration (AGE), the nature and forest administration (ANF) and the NGO Natur & Emwelt, this work was mainly carried out by Lena Hirschler, a Master Student in Biology at the University of Trier (WATGOV Working Paper 2). The engagement of leading experts and practitioners working on water quality in Luxembourg in a research-based co-design process allowed to better understand needs and possible ways in which citizen science can contribute to water governance in Luxembourg from diverse points of view.

The project is scientifically original in the way it conceptualised water quality as an emergent phenomenon in complex social-ecological, technological systems (König et al., 2021; Pickar, 2022), this is apparent both in the citizen science tool set's design and in the social processes for its design and use. New knowledge produced from semi-structured qualitative interviews, three workshops, and documentary review, includes a detailed and critical understanding of the implementation of laws and regulations relating to water quality, and the data landscape that supports regulatory action (König et al., 2021; Pickar 2022). Prevailing practices are discussed in relation to key criteria for adaptive governance in the literature. The doctoral researcher, then, examined different approaches to environmental citizen science in view of their potential to contribute to more adaptive surface water governance.

Furthermore, an innovative set of indicators on human-environment interactions to invite data collectors to reflect on their sense of place and how it may relate to their well-being emerged from the process (Pickar, Ph.D. Dissertation, WATGOV Working Paper 3 König et al., 2022). After exploration of diverse options to developing citizen science tool kits, including with colleagues at UCL, we concluded that the most resource efficient solution is to outsource it to an enterprise offering the programming and management of citizen science APIs and databases as a service. The enterprise Spotteron is at present programming the citizen science tool (they already host a related project with some relevant functions). The API is expected to be completed and ready for use by July 2022.

Contributory citizen science: Two public data collection campaigns

Public data collection campaigns: in 2019 and 2021 my team lead by doctoral candidate Karl Pickar and I organized two large sampling campaigns with a citizen science tool in collaboration with the Non-Governmental Organisation Earthwatch,'s subgroup Fresh Water Watch (FWW). There was significant media coverage both times (Luxemburger Wort, Télécran, Radio 100,7, amongst others). in 2019 we had 113 data points collected by over 80 engaged volunteers collecting and analysing water samples. In 2021 we had just under 311 data points by over 250 volunteers who used a detection kit to assess the nutrient content of water, suggesting awareness raising and learning (invited presentations at the **30. Wissenschaftliches Kolloquium der Deutschen Statistischen Gesellschaft** 'Von der Umweltstatistik zur Nachhaltigen Entwicklung'on 19.11.2021, and at the **European Statistics Day** organized by **the European Statistical Advisory Committee**: Workshop on non-traditional data sources and data science for official statistics' on 20.10.2021, and Stankiewicz et al., manuscript in preparation). The data clearly highlighted areas where water quality was of concern in that point in time and was considered by the national water administration. The data was complementary to official data in that it was geographically more spread out and included small streams in biodiversity rich regions.

A participant survey with 81 respondents suggested the campaigns contributed to awareness raising on water quality issues and possibilities for remedial action from an accompanying website we developed for the purpose (https://sustainabilityscience.uni.lu/nexus-futures_/citizen-science/ ; this site is being improved for the virtual Transformation-Lab site we will be launching this summer). The survey also indicates that a majority of participants are prepared to engage again, also on a more regular basis.

Corporate Social Responsibility programme: Furthermore, in the collaboration with Freshwater watch we worked with the bank RBC Dexia. The bank instituted a corporate social responsibility programme inviting their staff to contribute to citizen science data collection over time. At the initiative lunch time presentation 60 employees participated, and about 30 persons attended a training workshop to collect a more extensive data set on water quality. The staff self-organised and continued a planned sample collection over 12-month period in an area of ecological interest with sampling site suggestions by colleagues from the river partnership, finally 6 employees engaged over 12 months collecting 51 data points. The experience points at the potential of working with firms on a larger scale.

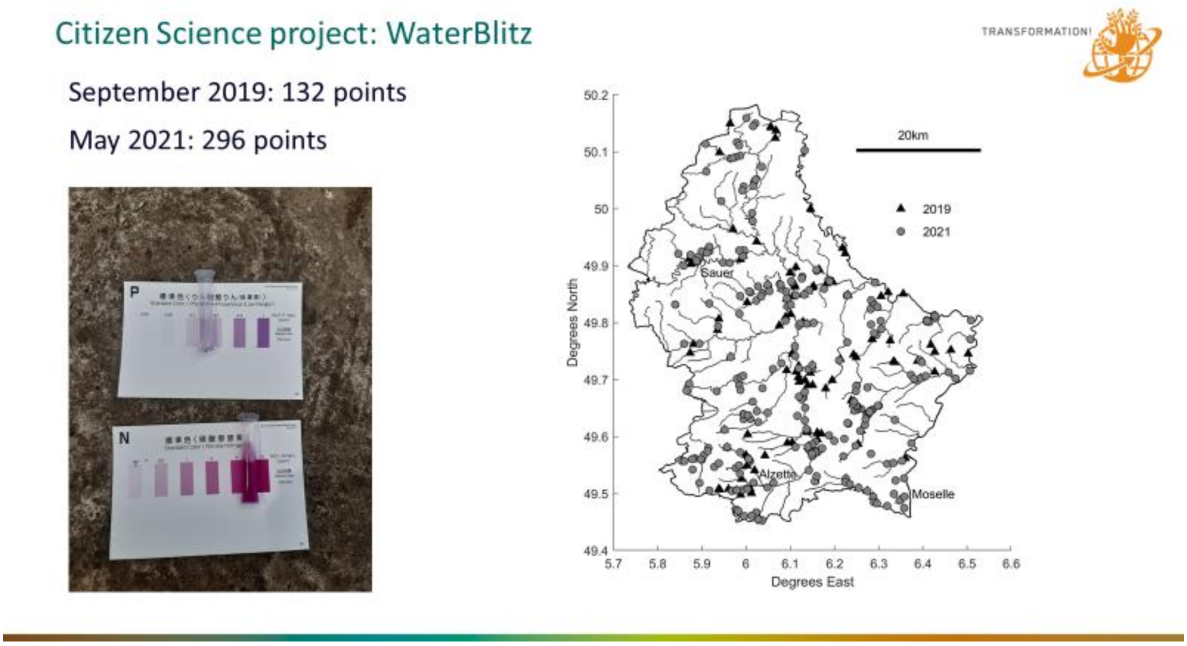


Figure 2.3 Data points from the 2019 and 2021 WaterBlitz campaigns

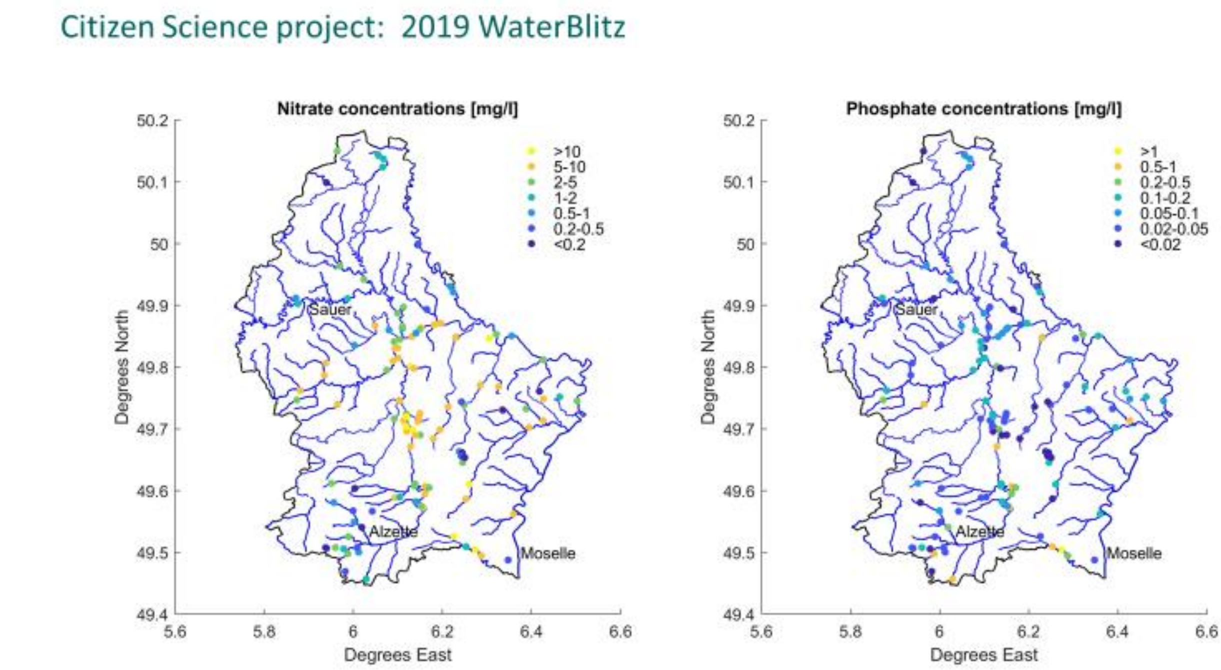


Figure 2.4 Data points with estimates on nitrate and phosphate levels at a wide range of locations across Luxembourg 2019

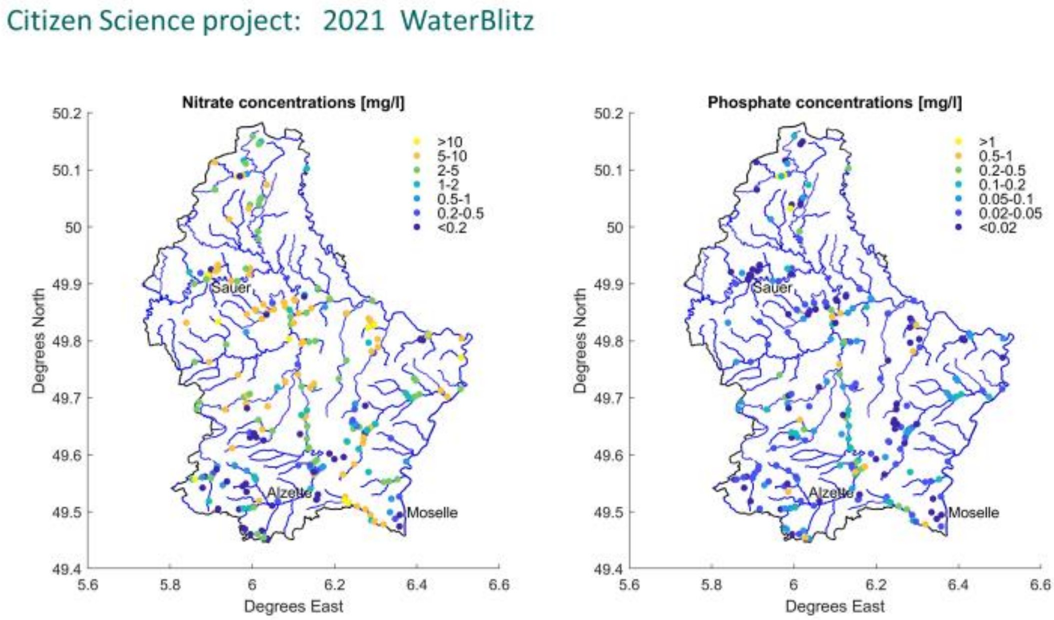


Figure 2.5 Data points with estimates on nitrate and phosphate levels at a wide range of locations across Luxembourg 2021

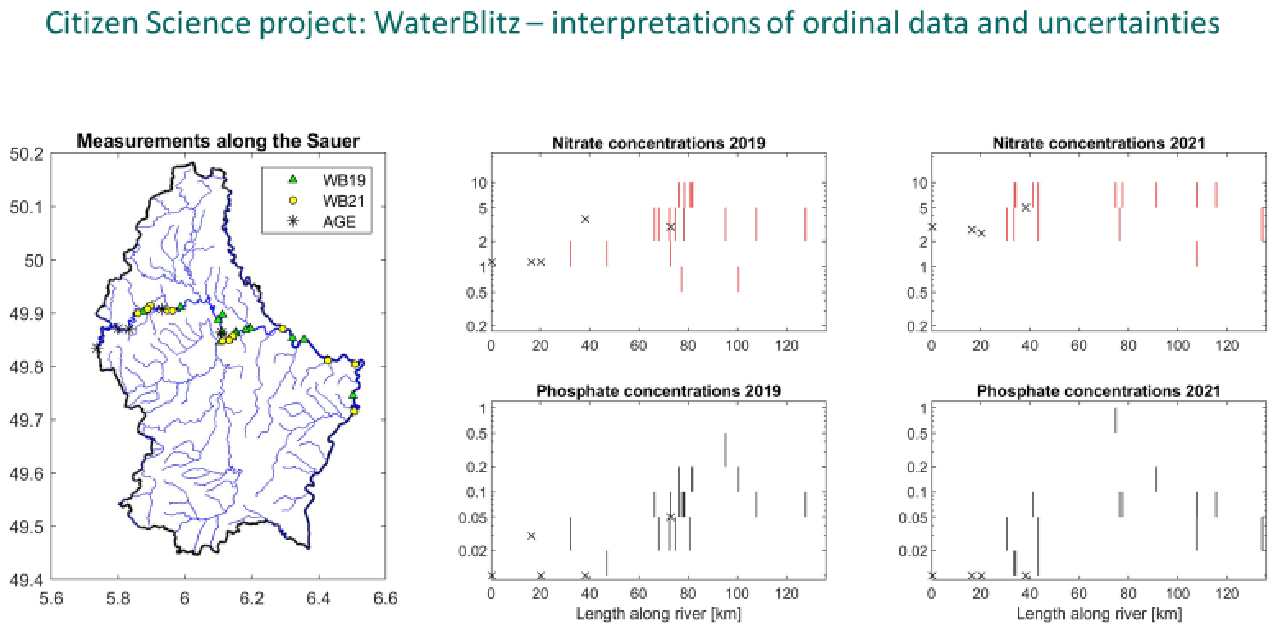


Figure 2.6 Comparison between Nitrate and Phosphate concentrations in the years 2019 and 2021 along the river Sauer

The nutrient concentration data, collected in the intervals, need to be understood as ordinal data. Categories can be ordered, but not compared. Using the guidelines for nitrate concentration to be below 5.7 mg/l for the water body to be classifies as “good”, the highest two nitrate concentration intervals could thus be classified as high concentration intervals.

Citizen Science datasets are characterized by specific uncertainties across a range of different dimensions ranging from adherence to sampling protocols, interpretations of colorimetric assays, with an untrained eye and potential mistakes in entering the data in the app. In our team we recommend quality control and expert review of collected data points. For volunteer groups that commit to recurrent data collection, training workshops are advisable. *It is a very common, yet very damaging illusion, that high uncertainty in science entails low quality. The key to quality being skilled management, not elimination, of uncertainty.*

Furthermore, the quality of data sets is from sporadic sampling that can be achieved with such *ad hoc* campaigns. It cannot be compared to data collected in rigorously planned and executed official data collection campaigns that are part of national monitoring programs instituted in compliance to the EU water framework directive. These campaigns however were positively surprising in how well spread sampling sites were across the country, and that they included a fair number of smaller streams, including important sites of aquatic biodiversity. Whilst the WFD (Water Framework Directive) mandates sampling of larger water bodies, ecosystems with particularly high biodiversity are also often found in smaller streams and ponds.

The data collected during the WaterBlitz events clearly provides valuable insight into smaller water bodies and gives indications of potential hotspots with elevated nutrient levels in sites, which are not usually sampled in official programs. Noteworthy examples included the Gander River: From the 10 readings sampling it, 3 recorded nitrate concentration in the highest available interval, >10 mg/l, and 5 further ones in the 5-10 mg/l interval. Also, some of the highest phosphate concentrations. In the Muellerthal Region: In an area about 10km across, 4 readings of nitrate above 10 mg/l and 8 between 5-10 mg/l were observed, with just 3 readings in other intervals.

Moreover, simple observations that may be documented with photographs may give important clues and warnings on possible sources of pollution in surface waters, such as drainage pipes, old or leaky containers for chemicals.

Difficulties that hampered the project

The onset of the pandemic and the start of the Lock-Down in March 2020 coincided with a critical phase of the Ph.D.'s research. Several planned collaborative participatory events had to be cancelled. The Ph.D. candidate experienced the dissertation writing process in such isolation as difficult. The quality of the output did not match quality of prior work of the candidate, due to the lack of social interaction (despite frequent WebEx meetings and chapter commentaries in the critical writing periods).

Nevertheless, most of the main research hypotheses were tested and most of the initial objectives were achieved. However, as the finalization of the definition of the indicators during the pandemic and implementation of the tool took longer than expected we could not proceed to develop exact guidance on how to institute a quality-assured scientific inquiry process, in which citizen volunteers, scientists, policy makers, administrators and private sector water users play a role. The literature review in the Ph.D. thesis as well as the two papers (one published and one close to submission) do however elaborate on the issue of quality assurance in more detail. We could not assess the use or learning of our tool, but instead worked with a suitable place holder of the Earthwatch tool.

In sum, from these first experiments with environmental citizen science for water governance in Luxembourg we addressed a set of three pragmatic research questions as follows:

- *Can volunteers be engaged to get any data at all?*
  Yes: Water Blitz, corporate programmes show very promising results.

- *What are issues with data quality?*

  Quality control by professional scientists is required.

  Large amounts data are required as they are ordinal.
- *Who can and will use this data – for what purpose?*

  Citizen science data can provide a useful complement official data when sampling rates are low, and it can flag potential pollution hotspots. (https://sustainabilityscience.uni.lu/nexus-futures_/citizen-science/)

We also concluded that it is more difficult to engage volunteers in more time intensive co-creative projects and co-design workshops. These activities were largely of interest to professionals working in related roles in NGOs or water management or engaged on environmental committees of municipalities. Both contributory and co-creative citizen science approaches have a place in fostering public engagement in water governance.

In general, our research including the survey of participants in the WaterBlitz supports that non expert citizen can become more meaningfully engaged when they are empowered and equipped to collect data about their own environment. Advantages for public engagement in governance thus include that citizen can:

- Gain own experience: Civilians come to understand the nature of scientific knowledge, the meaning of data (validity & reliability) better when actively engaged in scientific inquiry
- Build own local capacities and expertise: Civilians discover how easy and quickly one can become an expert in a specific issue in their own local environment
- Access without great costs: Access to cheap ICT (information and communications technology) with enormous monitoring and storing capacity makes 'doing science' easier and more affordable
- Learn to assess and evaluate dynamic complexity of environmental processes: Monitoring social, technological and environmental change in parallel for reflection about complex systems and how to better act upon them is in reach now
- Gain awareness of consequences of own actions (household contributions) by self-monitoring the impact of one's own actions, one can become more reflexive and effective in bringing about change

Next steps

The reference group has decided that individual free use of the app should be limited exclusively to collecting observations, even in data collection campaigns. Accordingly, the WasserLux app will be set up with a button at the very top that differentiates between free observations and measurements (this has already been clarified with the programmer). The observations that can be documented by the app are supplemented accordingly by the parameters of the disturbance factor analysis at the Syr. These factors also provide a basis for analyses based on the beam effect concept. Further preliminary work on the visual survey by non-experts of relevant information on structures by German researchers is also being considered here (Meier et al. 2011).

An app, which serves to collect the disturbance factors and easily visible structural parameters of stream impact models, can then potentially be used by all river partnerships to create a comparable mapping of the different river basins on a website.

The adaptation of the app for this purpose has been in progress since the reference group meeting with the programmers in June 2022. A draft is being coordinated with Alexandra Arendt and Stephan Müllenborn (River Partnership Syr) and Nora Wellschbillig (AGE).

The supplementation of observations with quantitative surveys using toolsets (e.g., Secchi Tube for turbidity/sediment content determinations and test kits for chemical substances) should only be carried out by appropriately trained persons who have taken part in train-the-trainer workshops at the university or workshops run by appropriately trained trainers. If the button 'Measurement' is clicked, a field should appear in which a number for the identification of the test kit is entered and/or automatically generated, so that later, through additional documentation, a clear assignment is possible as to which type of test kit was used at the location. We will organize a joint data collection event with all interested parties after the summer for the inauguration of the app.

A simple didactically prepared toolkit for teachers and students and guided walks in nature parks and exhibitions will be developed before March 2023. This will include instructions for conducting chemical analyses, standard operating procedures, and details of where and which appropriate strips and reagents can be ordered online. Instructions for quantitative surveys will be developed with Jo Hansen and his laboratory manager. Instructions will promote surveys that may reveal incidents with sewage treatment plants (e.g., by determining ammonium concentrations).

The encouraging outcomes of the citizen science project strengthened our resolve to dedicate the next 10 to 15 years to further facilitating the establishment of innovative structures and practices for evidence-based learning for the regeneration of the life support system through place-based actions and policies in cross-scale participatory processes including with citizen science approaches. We will extend these activities internationally with our network of partners. The ministerial support for a five-year follow-up project on drought resilience with a citizen science-based early warning system has just been secured. The citizen science approach that emerged from this project is one of several pillars of our national Transformation Lab that we will launch with our partners in government and NGOs in the summer of 2022 (https://transformation-lab.lu/?ucp-access=ea7f3880).

A five-year follow-up project with a focus on drought resilience with a citizen science-based early warning system has just been secured.

3. NEXUS FUTURES river basins: Systems perspectives on sustainable water governance in two river catchments

By Kristina Hondrila

Research purpose, topic and description of case studies

The main purpose of the research was to support sustainability transformations by providing insights on what makes knowledge actionable and facilitates social learning among diverse professionals and, on that basis, to offer approaches and recommendations on how governance processes may foster knowledge and agency for sustainability in river basins.

With a point of departure in the EU Water Framework Directive (2000) and the national *Loi relative à l´eau* (2008), the project addressed the question "How can governance support social learning and actionable knowledge for a sustainable engagement with water and land?". In the framework of case studies, it examined how diverse actors organised in the Syr and Upper Sûre river partnerships have sought to improve water quality in the surface water bodies in their river basins since 2000: water and nature organisations (incl. syndicates), municipalities, farmers and farm advisors and national authorities. At the Syr, the focus was on river restorations and reductions of pollution from wastewater in and around Natura 2000 areas (particularly, Schlammwiss-Brill); at the Upper Sûre, on reductions of nutrient and pesticide inputs from agriculture in (planned) new drinking water protection zones. Against the backdrop of an inquiry into social-ecological-technological interplays between society, regulation, organisations, professional practices, technologies, and landscapes in the river basins since the 19th century, the research focused on if and how post-WFD governance processes have fostered social learning and knowledge that have supported joint actions.

Explanation of key terms: The project adopted a broad understanding of governance as encompassing both *formal* regulatory processes and *informal* purposeful self-organisation of nongovernmental and governmental actors, devoting particular attention to their interplays. Social learning was defined as entailing changes in social relations, knowledge and actions that strengthen collective capacities to address challenges, notably by fostering actionable knowledge. Knowledge was broadly understood as encompassing understandings, skills and practices through which individuals make meaning of and engage with the world. *Actionable* knowledge for *sustainability* was considered to inspire actions and changes in professional practices that aim to protect and regenerate aquatic and terrestrial ecosystems.

Research approach and methods

The focal topics emerged in close cooperation with members of the NEXUS FUTURES reference group, notably the Syr and Upper Sûre river partnerships, and a wide range of other actors who provided suggestions and feedback throughout the study. The project was based on the triangulation of data generated via diverse methods:

- **2 workshops** with diverse participants (Syr: 21, Upper Sûre: 33): **collaborative conceptual systems mapping** served to elicit diverse perspectives and enhance shared understandings of system dynamics and drivers of change relating to water and land challenges in the river basins (e.g., water quality) and how to address them (**action fields**)
- **58 semi-structured interviews** with nongovernmental and governmental actors (agriculture: 19, environment: 10, water sector: 19, transport: 1, cross-sectoral: 8) that were selected based on purposeful and snowball sampling and analysed qualitatively

- **Observations** at **17 guided visits** to farms, protected areas, and water facilities and at **15 stakeholder meetings** (working groups, colloquia, public information meetings, etc.)
- **Analysis of more than 200 documents:** EU and national laws and plans, organisational documents (statutes, mission statements, reports), scientific studies, press articles

Analytical framework on social learning and actionable knowledge

An analytical framework was developed to evaluate the emergence of social learning and actionable knowledge in governance processes. It combines a systems perspective with an actor-centred approach by situating learning, knowledge, and action in interplays between individuals (personal sphere), actions (action sphere, e.g., in river basins), professional and organisational contexts and macro-contexts of society (social and cultural sphere, regulation) and the biosphere. The framework builds on the concept of narratives to connect professional knowledge and practices to meaning-making and identities of individuals and groups (especially farmers, water managers, environmentalists). It thus allows for the analysis of multiple factors that may both *influence* social learning (as enabling or hindering factors) and *change* as a result of *outcomes* and *effects* of learning processes:

- **Informal:** personal and shared knowledge, narratives and identities of individuals (personal sphere) and of professional groups and organisations in the Syr and Upper Sûre basins and their river partnerships
- **Formal:** organisational missions and structures, regulatory frameworks, processes and management plans, related scientific studies and data
- **Material:** states of ecosystems (e.g., water bodies), physical actions, measures and practices, technologies and infrastructures, financial/economic resources

The framework encompasses four dimensions to analyse differences in how diverse professionals understand challenges and, moreover, to evaluate if and how social learning fosters shared understandings that support joint actions, while also taking into account complexity, uncertainty and ambiguities of sustainability challenges:

- ***Who:*** actors from *diverse* sectors (e.g. agriculture, water, environment) and levels
- ***Why*** (normative dimension): understandings of challenges and purposes pursued
- ***What*** (systems dimension): understandings of cause-effect relations
- ***How*** (transformation dimension): action strategies, means, practices

These dimensions also serve to analyse how professional groups and organisations relate to anthropocentric paradigms in water management (command-and-control) and agriculture (productionism) that policies since the WFD have sought to overcome by prioritising environmental protection (ecological restoration paradigm) and adaptive and integrated management. The latter promotes informal governance based on public participation and social learning in multi-actor networks as alternatives to hierarchical governance; furthermore, it privileges nature-based and preventive measures (such as river restorations and agroecological practices) that are experimentally adapted to (changing) contexts over technological ´end-of-pipe solutions´ that have been characteristic of command-and-control and productionist paradigms.

Overarching findings

The case studies provide evidence for how governance can foster social learning and actionable knowledge. The inquiry finds that knowledge that is to be actionable in the service of sustainability needs to *resonate* with, but at the same time *challenge* and *alter* the professional knowledge, narratives, and identities of professionals. These are often shaped by historical paradigms that are deeply engrained in organizations (incl. in education), legal frameworks, landscapes, and infrastructures in the river basins. At the same time, the case studies show that governance, indeed, can foster social learning that open up for paradigm shifts by enhancing opportunities for actors to self-organize, take action and engage meaningfully with each other as well as with water and land. At the personal level, learning effects identified have included changes and convergences in the purposes (why), systems understandings (what) and professional practices (how) among participating actors in the Syr and Upper Sûre basins who set out to improve water quality. Most notably, some farmers have begun to see themselves as "drinking water producers" (*in addition to* being food producers) and sought to reduce environmental effects of their practices. As regards organisations, farmers and the water supplier SEBES have set up a new formal organization (LAKU) to cooperate in this effort, supported by the Upper Sûre nature park and river partnership and public authorities. Some municipal and public water managers, too, increasingly cooperate with environmentalists "to give more space to water" (e.g. via river restorations) for nature-based flood protection and water quality improvements, *in addition to* technology-driven efforts. Finally, *in addition to* being "nature protectors", environmentalists in intermunicipal syndicates and nongovernmental organisations increasingly regard themselves as "partners" of farmers and other actors, with the river partnerships acting as boundary organisations that provide knowledge and resources for cooperation. These learning effects provide some indications that dominant paradigms in agriculture, water management and ecological restoration may gradually expand and open up towards one another, supporting more adaptive and integrated approaches.

Decisive facilitating factors have been self-organised activities between highly committed individuals and organisations that served knowledge co-creation (from diverse professional and scientific knowledge and data) and experimentation with agricultural (Upper Sûre) and hydro-morphological (Syr) measures. At the same time, social learning in the river basins has so far remained limited, with only few individuals and organisations participating actively and revising their practices. Despite EU WFD obligations, water quality in Syr and Upper Sûre water bodies has hardly improved. Governance processes have also produced a number of *unintended* effects (incl. disappointed expectations of some actors) and uncertainties about future cooperation. The main facilitating and hindering factors are summarised in table 3.1.

	Facilitating factors	**Hindering factors**
Individuals	• strong sense of purpose & *identification* with profession • belief in possibility "to change things" (*self-efficacy*) • eagerness to "constantly learn" (*reflexivity*), "work together" (*interdependence*) to develop measures adapted to con*text considering complexities (systems thinking)*	• weak sense of purpose and professional identification ("I no longer have visions") • sense of having "no influence", being "marionettes", "stuck in a corset" (*powerlessness*) • sticking to established sectoral understandings and practices • lack of trust and "us-against-them" narratives (*polarisation*)
Action sphere	• frequent informal interaction • learning-by-doing • knowledge co-creation tailored to purpose & context, including prof. and scientific knowledge • access to land	• little informal interaction, few joint activities • shrinking *physical* spaces for nature-based measures (local land availability) • "huge" ecological pressures
Organisations & professions	• *histories of cooperation* (incl. regional identity in river basins) • *organisational commitments* to self-organisation, cooperation • Cross-sectoral and –scale *social networks* and mediating *boundary*	• Absence of shared identities • Weak/tense cooperation, lack of trust, "us-against-them" • sticking to established and formal mandates, procedures and plans

	organisations (e.g. river partnerships, syndicates, farm advisory services)	• *weak (inter-)organisational commitment:* little ´leeway´ for actors to engage informally
Society	**Formal regulation:** • coherence, coordination • flexible plans, admin. processes • active stakeholder involvement, clear mutual expectations and roles • public funding possibilities **Social and cultural sphere:** • demand for regional products • appreciation of habitats, food	**Formal regulation** • lack of coordination, priorities ecological & social concerns • rigid frameworks, bureaucracy • neglect of prof. knowledge • weak stakeholder engagement, support, unclear expectations **Social and cultural sphere:** • low demand for reg. products • lack of appreciation
Material & biosphere	• ecological regeneration capacities	• ecological deterioration limiting impact of local actions

Table 3.1 Facilitating and hindering factors in governance processes

Conclusions and recommendations

The dissertation provides an analysis of prevailing paradigms and narrative identities and understandings of self-efficacy associated with diverse professions from walking interviews, workshops, and documentary analysis.

The thesis characterized how somewhat technocratic, expert-based governance approaches can direct flows of resources and attention in ways that present barriers to situated regenerative actions by local actors:

- **Fragmentation of knowledge fields undermines connectivity across expert disciplines**, **policy-areas**, levels of governance, professions, and largely prohibits an understanding of complex interactions across different spheres from which prevailing patterns of behaviour emerge.
- **Confirms and stabilizes existing power structures and reinforcing loops of distributional issues in relation to knowledge, capital and power**. **'Objective' science legitimized through established criteria for excellence and peer review often serves to** confirm prevailing framing of goals and issues avoiding or delegitimizing questions that challenge prevailing knowledge and patterns of behaviour favouring alternatives.
- **Unique** authority of science and expertise with claims to 'universality' based on abstract models or frameworks can **silence place-based knowledge and local concerns and capacities and interests. Enhances disconnections across spatial scales** and levels of governance.

Monitoring and measurement regimes:

- Top down fixed-type knowledge accountability and measuring regimes contribute to rigidity trap by directing all attention and resources to specific cause effect relations – closing down opportunities to direct attention and analysis of others that may matter more in certain situations/places.
- Statistics and indicators often assess just the level of a stock rather than trying to understand flows and feedback in terms of rates of replenishment or degradation of a resource and interdependencies between various sub-systems.

In that, the research demonstrates that scientists can play a role by providing approaches, methods and tools that facilitate the co-design, implementation, monitoring, and evaluation of sustainability projects among diverse actors.

In more general terms, the insights gained from this research project suggest that water and land governance and management in Luxembourg are characterised by growing contradictions and shrinking spaces for self-organisation that pose barriers to social learning and actionable knowledge among professionals. Growing contradictions arise from the continued dominance of productivity-oriented paradigms that stand in conflict with – and partly seem to jeopardise - environmental objectives as they result in growing pressures on ecosystems that, physically, limit local land availability and (potential) positive ecological effects of local actions. In addition, the EU WFD (Water Framework Directive) and other environmental policies have strengthened managerial and hierarchical governance in Luxembourg, relying strongly on detailed pre-defined management plans and specialised expertise, despite the creation of river partnerships and introduction of public consultations. In general, water and land governance and management are more regulated when compared to pre-2000, with cumbersome administrative authorisation and funding processes that rest on pre-defined criteria that hardly take into account social concerns and factors. Water and land governance has become more integrated *formally*, but not more practice-oriented and *adaptive*.

Facing multiple constraints to acting, tensions and contradictions in the policy landscape and workings of the economy (e.g. global vs. local market mechanisms), many actors have little time and resources to self-organise beyond their established communities and beyond "working off" plans and daily tasks. As a result, spaces for not only self-organisation shrink, but also for meaning-making. While a strong identification with one´s profession is a major driver of pioneering action, systemic constraints risk reducing the fulfilment professionals find in their jobs and fuelling narratives of powerlessness and division.

*How can governance be improved to facilitate social learning and actionable knowledge? S*ocial learning requires concrete projects and joint activities that build trust, nurture narratives of self-efficacy and interdependence and expand spaces of action and imagination. Two priority action fields have emerged from the NEXUS workshops and case studies:

- strengthening regional initiatives in agriculture that create alternative perspectives and pathways for farmers (e.g. community-support agriculture, regional products)
- making river restorations part of projects to reinvigorate ecological and local community life, bringing together diverse professionals, scientists, and local citizens

As regards formal governance, projects such as these would benefit from:

- policy coherence between water, environment, and agricultural policies
- flexible regulatory frameworks and administrative procedures (incl. one-stop-shops)
- a stronger consideration of professional knowledge of practitioners, including in participatory and collaborative processes

As regards informal governance, more could be done by nongovernmental and public organisations in terms of

- encouraging staff, members, and partners to engage in informal intra- and inter-organisational cooperation
- strengthening commitments to boundary organisations such river partnerships, nature parks, farm advisory services and other mediating organisations (in terms of participation, resources, visibility, and mandates)

5. NEXUS FUTURES Scenarios on how we engage with water and land.

By Ariane König
From prediction and control-based management to coping with complexity, open futures, uncertainty, and accelerating change with scenarios.

Why scenarios?

Scanning the future with scenario analysis and back-casting approaches in participatory processes help understand conditions of complexity, uncertainty, potential disruptive changes, and human choice and constraints (Robinson et al., 2011; Wiek and Lang, 2015). Exploratory scenarios are stories describing future worlds that illustrate alternative outcomes of developments. Exploratory scenario building engages research to better understand drivers of change, certain and uncertain, in a contextual environment we can't influence. The approach blends qualitative and quantitative analysis to explore alternative outcomes of global change and associated implications locally in the transactional environment, where some changes might be brought about if a critical mass of stakeholders engages. A set of scenarios usually serves to highlight things we can or can't know about the future, uncertainties that matter but are rarely talked about, and inter-dependencies in alternative future development paths, human choices and constraints, and differential power distribution in society. Sets of scenarios may also be designed to sketch *the interdependence of culture and values prevailing in society and how these are interdependent with technological choices*; this may also be related to experienced quality of life and environment and how distributional issues might play out in different futures. This dimension is however often neglected.

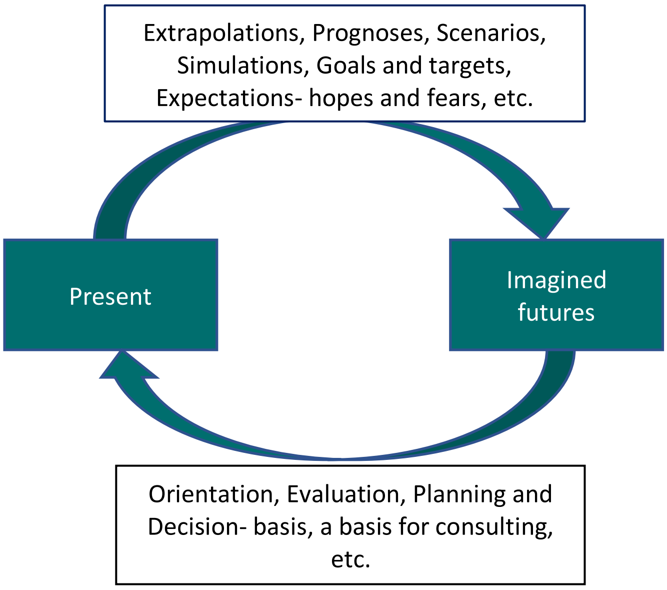


Figure 4.1 Working with Futures.

Transformations for sustainability can only be justified with reference to the future. Shared ideas on futures help orientation and the development of more robust strategies and action plans. The process and evaluation allows drawing together diverse types of knowledges and expertise, and to understand diverse perspectives and opinions.

Table 4.1. Comparison between three approaches to work with futures

	Forecast/PROGNOSE	Vision	A set of scenarios
Question of Purpose	What is our best estimate, based on available and representative data, of what might happen?	Where do we want to be?	What are diverse views on what might happen and what we don't know?
A representation of	A most likely state, and derived states	A single most desirable future	A set of alternative **open f**utures
Method	Mainly quantitative	Mainly qualitative with associated goals and targets	A mixture of qualitative and quantitative, with emphasis on stories
Process	Expert-driven	Community-driven	Trans-disciplinary
Relation to values in a pluralist society	Claims to be objective	Normative	Alternative worlds highlight disparate sets of values and world views and priorities
Risks and uncertainties	Hidden	Hidden	Revealed
Function: Helps to analyse	What are the likely implications of 'business as usual'?	Where do we stand now in comparison and how can we go about achieving this?	What are the implications for me and us?

The scenario approach in general terms

Complementary to the well-established fields of knowledge in disciplines, scenario work as a research approach allows to create knowledge about dynamic connections, relationships, and resulting patterns of behaviour in complex socio-ecological-technological systems, to see the future not only as a linear time process but to envisage dynamics from which patterns of behaviour are stabilised or undermined, which also make feedbacks between the areas visible. In short, it is a method that enables future-oriented cooperation across differences for systemic change towards sustainability. Qualitative scenarios and systems assessments are not the only sensible way. But they promise to help us see and approach problems in a new way and to identify possible areas of influence to help shape our common future. Sometimes these methods also point to unexpected possibilities. These methods are not yet widely used in policy and practice in Luxembourg.

In general, strategic scenario approaches rely on participatory processes in which diverse stakeholders consider salient, plausible and challenging future developments in an open but at the same time structured manner. One claim is that the chosen approach helps to generate dialogue and understanding across differences in interests, expertise, and worldviews. Thus, common action fields and consequences of action and non-action can be debated between diverse actors in a structured, systemic, and forward-looking manner, with reference to a 'safe' space in the future that plays down vested interests in the present but emphasizes future shared risks and uncertainties.
In such dialogs across different sectors and expertise that have concrete and locally specific cases and reference points, different types of knowledge and experiences, as well as hard and soft facts and perceptions can be drawn together for meaning making. One prime advantage is that participants in such discussions then do not automatically end up drawing on past experiences or making reference to past development paths to make recommendations for present or future actions, but are invited to face and address risks, uncertainties and entirely new possibilities that in more traditionally set meetings can easily be evaded.[5] The method of the Oxford Scenario Programme (Ramirez, 2016)

5 Siehe u.A. auch https://www.umweltbundesamt.de/themen/nachhaltigkeit-strategien-internationales/strategische-zukunftsforschung .

was developed to help distinguish between the contextual environment that can be better understood, but which is difficult to influence, and the transactional environment that can be influenced if a sufficient number of actors collaborate (see Figure 4.2).

How can we learn to take decisions and actions today to safeguard our most-existential needs with respect to water and food provision across scales of social organization? Reference to past-experience will not suffice in times of increasingly turbulent global and local change, we need capacity- building to embrace the future as open and amenable to our influence on some extent, as we bring forth our world that we perceive and act in. The goal of this work-strand is to develop scenarios that help us to better recognize and act on our own sphere of influence we have for shaping the future of how we engage with water and land more sustainably in Luxembourg (and beyond?), as individuals, as organisations, as policymakers at the national level, and in (international) networks. In this project, with the help of a scenario approach we address the need for capacity building for new ways of thinking and acting along four dimensions:

- **Complexity:** Decisions that shape our engagement with water and land in Luxembourg are complex and touched by a vast network of interdependent but sectoral formulated policies and practices, including in the areas of environmental protection, agriculture, economic development, and immigration. Our education taught us to break problems down into small parts and linear cause-effect chains rather than to think in terms of mutual causality and relations. One unanticipated consequence of the heat wave combined with months of scarce rainfall was a drastic change in behaviour with respect to water consumption, which nearly doubled across all closely monitored municipalities. There are clear feedback loops between human behaviour and environmental change.
- **Contingency:** Issues relating to water / land access and use are different in each river basin, local and national perspectives on appropriate measures and priorities can diverge.
- **Open futures and uncertainty**: Moreover, similarly as in the question on pensions, given our dependence on large but quasi invisible and unspoken of infrastructure networks and technologies for water supply and treatment, decisions have long-term impacts – intended and unintended. We are used to management approaches that rely on prediction and control, assuming that all actions and their consequences are knowable, that do not serve us well in today’s highly complex and rapidly changing world.
- **Different sets of values and contradictions**: And even if we had a clearer picture of future options and their consequences, we would soon squabble over dilemmas and tough trade-offs. How can we evaluate future consequences of decisions today, if we do not know what the future might look like, and if it is not actually ourselves who have to bear the full brunt of the consequences of these decisions.

Main advantages of the method for qualitative scenarios we are further developing include that:

- Qualitative scenarios offer plausible representations of possible future developments that describe what the future might look like. Contexts that could shape our future are systematically thought through when creating these images of the future. Plausible sets of formative contexts are assembled into inherently coherent future scenarios.
- The future is open: Since qualitative scenarios always involve the creation of several such scenario sets, of which developments in one scenario often contradict those in another scenario, the future is presented as open; the creation of self-consistent worlds demands networked thinking. Broadening the horizons of the people involved.
- Collaborative scenario work helps us to relate to different expertise, interests, worldviews and values, to link knowledge across different sectors, and to connect hard and soft facts. Create structured discussion processes on topics relevant to the future. Groups with very different people, can thus jointly identify and evaluate fields of action and decide which actions they would like to support together that go beyond the sphere of influence of individuals.

- Working with the different futures as a framework for thinking and analysing then offers the possibility to better understand options for action and their possible consequences under very different circumstances. Working with scenarios helps to question one's own assumptions, to leave behind old thought patterns that may no longer apply, to better understand one's own sphere of influence, and to look at new possibilities for action together with actors from other sectors. Thinking in options, uncovering blind spots, generating orientation knowledge.

How can the scenarios be used?

The scenarios offer a framework for structured dialogue with constituents with different interests and expertise to think out of the box. Scenario sets can be a useful tool at different levels and stages of stakeholder engagement. Scenarios help to distinguish between contextual sphere and transactional sphere to better understand ones own sphere of influence given interdependencies between how global and local situations evolve. They help us better to understand our sphere of influence - the 'transactional domain' - and to discuss it through future-oriented questions:

- Why should we, and how could we, save water and reduce pollution?
- How can we change our consumption or forms of water treatment?
- How can we get involved politically, at work, or in a local community?

The scenarios also clarify which areas in our contextual environment we can only influence to a limited extent or not at all. These are also conditions shaping our dealings with water and soil. Examples include global technological developments, changes in weather patterns or geopolitics and power structures.

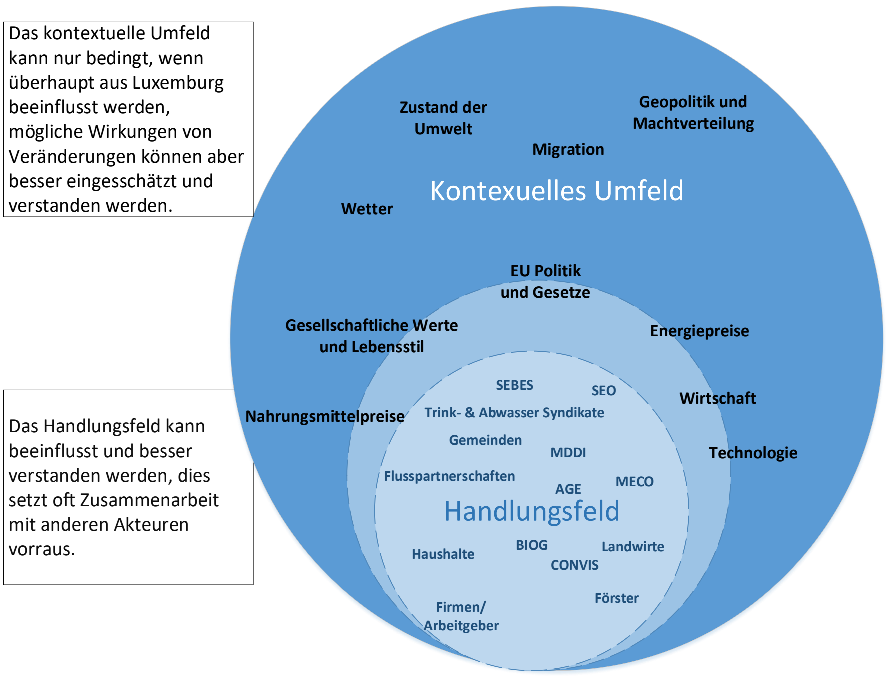


Figure 4.2 Influence diagram between contextual- and transactional environment

As an introduction, following is a brief description of two main ways how scenario sets can be used:

Scenario sets as a "wind tunnel" for decision-making: Scenario workshops can be designed to guide initial ideas, project and strategy development to be more future-oriented and robust. For this purpose, a specific wind tunnel method is used, which was also applied in the 3rd NEXUS scenario workshop.

Scenario sets as a basis for visioning processes towards a desirable future: A wide range of organisations such as businesses, associations, communities, and local governments can use scenario sets as the outset of a participatory process to co-create a vision towards a desirable future. Such a co-created vision can then be used in a second stage to assess the current situation (what is) to identify priority leverage points that should be addressed first to be able to move towards the desired future. This in turn can provide a strong foundation to develop action plans with specific projects and aims. This process can support the development of comprehensive policy initiatives to steer unfavourable current pathways towards the desired future vision.

Participatory processes that utilise scenarios to develop a vision are especially useful when large groups of stakeholders with diverse worldviews wish to collaborate. The visioning process with scenarios facilitates a collaborative approach to identifying risks, which everyone wants to avoid, and to identify new possibilities that are attractive to all involved.

Both of the above methods can help individual participants and collective groups to better understand their impact and opportunities for developing new pathways. These methods also create the space and time to consider a wide range of options, to uncover blind spots and knowledge gaps and to generate knowledge that helps orient rather than jumping to solutions. Ultimately, these methods can assist people and organisations to expand their horizons.

The participatory process from which the NEXUS FUTURES scenarios emerged

The participatory process to develop these scenarios involved over 50 interviews to understand diverse perspectives and world views from various stakeholders including regulators, administrators national and local governments, informal organizational actors such as the river partnerships, consultants, teachers, forestry, nature protection as well as users in the private sector and in private households and organized civil society.

Furthermore, we organized three workshops with 40 to 50 participants from diverse organisations, including public agencies involved in water and forest management and agricultural advice (AGE, ANF & ASTA), actors from river partnerships, municipalities, and the farming communities, as well as NGOs (CELL, Greenpeace) and intergovernmental actors such as the European Investment Bank. The report that this executive summary serves to introduce, describes three main workshops that have helped to develop a scaffold first prototype for the scenarios. (See Figure 4.3)

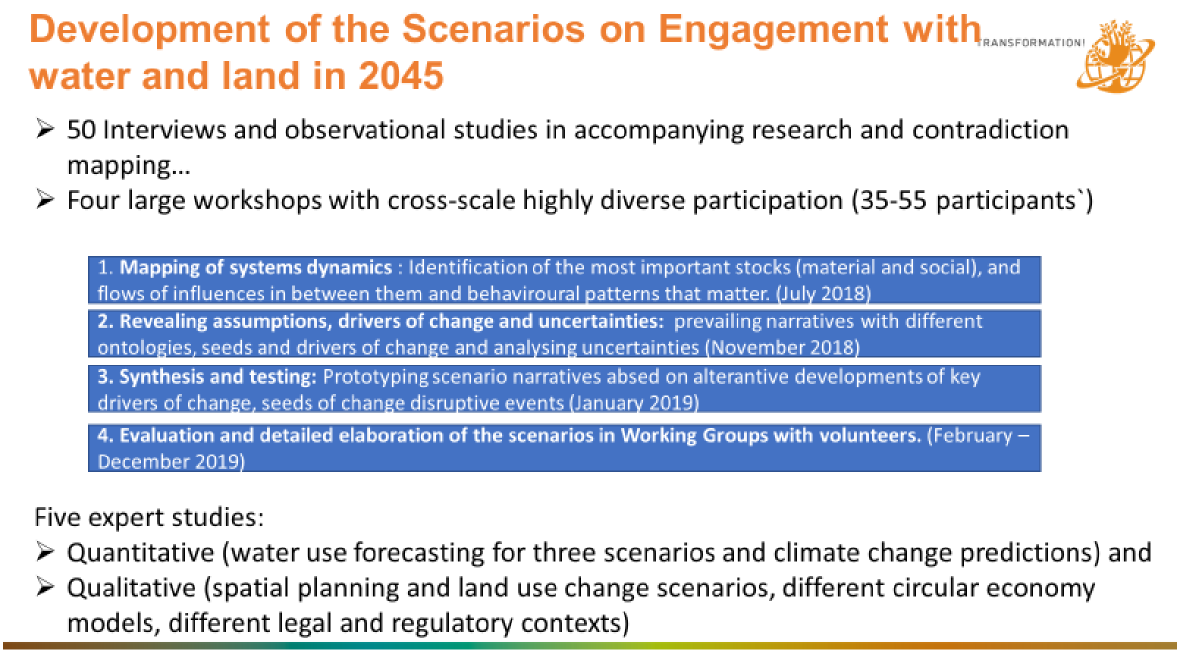


Figure 4.3 Development of the Scenarios - Schedule

From interviews we developed contradiction mapping, in workshops we used the method of collaborative conceptual systems mapping to identify what approaches to governance and supporting experimentation and action might make sense from perspectives of the disparate actor groups from different sectors and levels of governance.

We worked with five experts in different salient domains to enrich the three scenarios with differentiated narratives and quantitative estimates pertaining to:

1. Andrew Ferrone, Impacts of climate change in terms seasonal and regional distributions of rainfall and temperatures.
2. Alex Cornelissen et al., Modelling three water use scenarios for 2045.
3. Kai Böhme and Sebastian Hans, Spatial Foresight, Spatial planning principles and resulting land-use patterns.
4. Paul Schosseler, +ImpaKt, Three scenarios for implementing the circular economy.
5. Expert contributions 5 a/b, on the legal context of water governance, “Histoire d’eau et son Contexte juridique” (July 2018); “Gewässerschutz und Mitwirkung der Öffentlichkeit" (February 2018)

The merit is at present focused on the scenarios as a tool to create a different kind of space and process with the help of conceptual and methodological tools for changing the science-policy-practice interface that transcends traditional boundaries and power asymmetries and offers new connections and information flows across scales of governance.

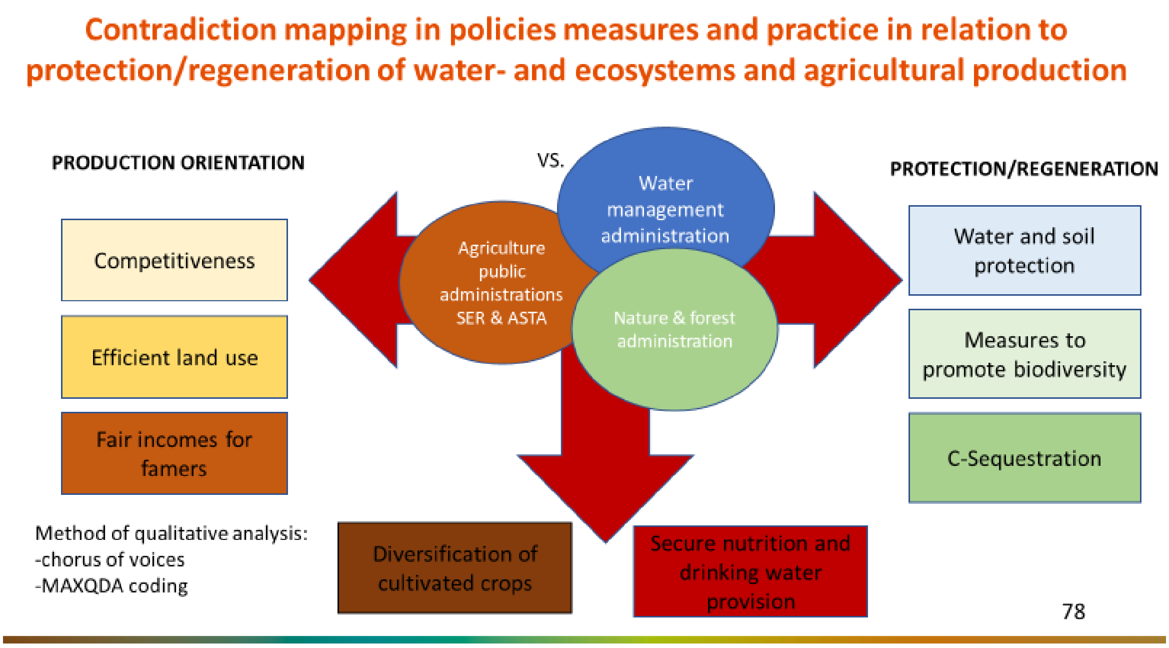


Figure 4.4. Main areas of contradiction mapping from the interviews.

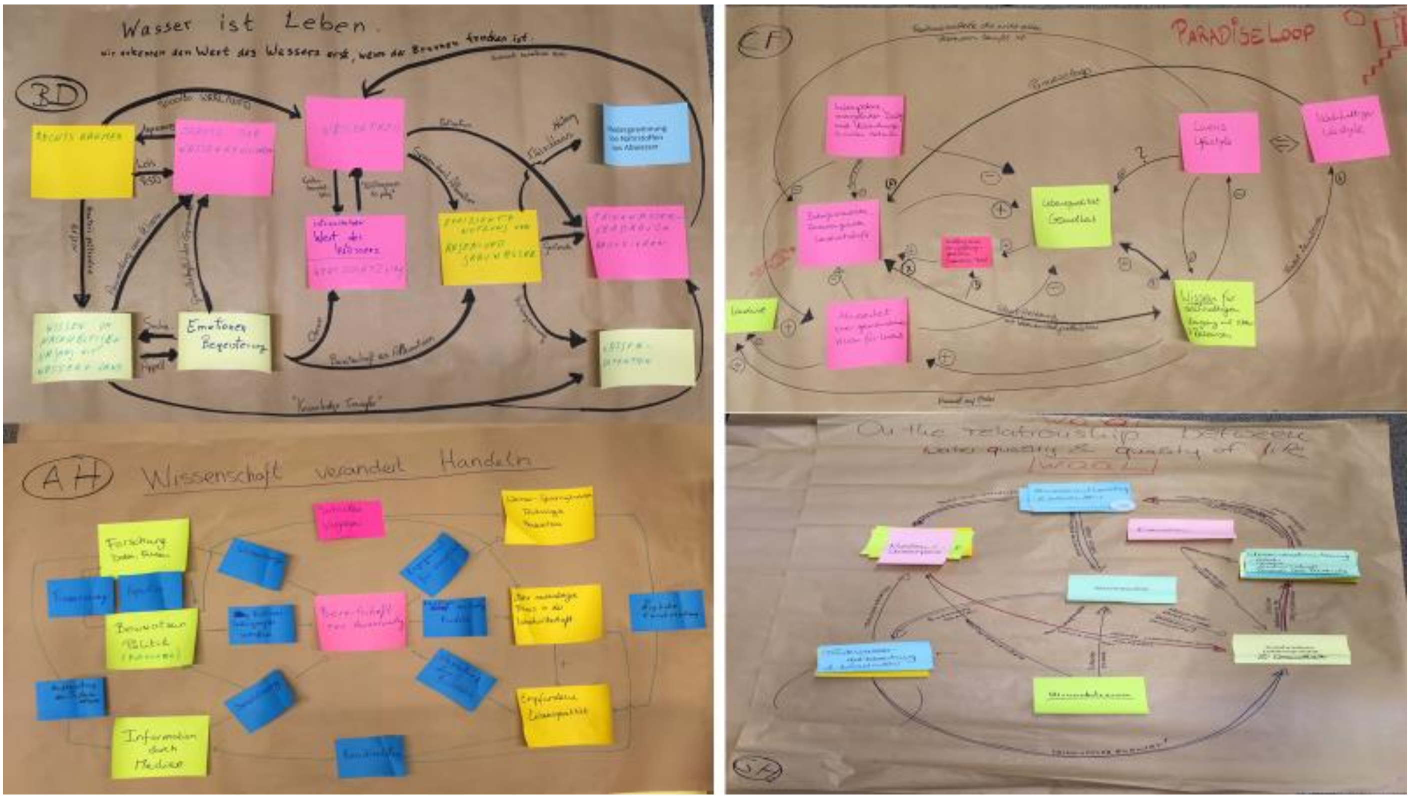


Figure 4.5 Collaborative conceptual systems mapping to narrow down factors that matter, understand influences between them, and identify action fields for system change.

Table 4.2 10 assumptions that help shape the management of water and soil in Luxembourg
The ten assumptions that received the most voting points are shown here, in total, 112 basic assumptions were written on cards by the 37 participants

	Category*	**Acceptance**	**Voices**
1	Personal area	Something should be changed, but it must not cost anything, and I must not be impacted by it (NIMBY effect).	11
2	Nature & Environment	Lack of clean water is not an issue in Luxembourg	10
3	Society/ Economy/ Politics	Modesty and contentment (in contradiction to) capitalism	9
4	Society/ Economy/ Politics	Private water consumption does not lead to environmental pollution. Only agriculture and other business contribute to it.	8
5	Nature & Environment	Soil is soil. No qualitative differences there, regenerates "automatically"; no matter what it is used for.	8
6	Nature & Environment	Ownership is ignored (keyword compensation) -> leads to conflicts and prevents cooperation	7
7	Technology/ Infrastructure	Luxembourg's water supply is inefficient (Lux. has more water suppliers than the Netherlands)	7
8	Technology/ Infrastructure	Water management = engineering problem	7
9	Personal area	that Luxembourg's drinking water is not of good quality, so we prefer to buy bottled water in (plastic) bottles, which is healthier.	7
10	Personal area	"I, as a small citizen, can't do anything anyway" -> Politics, large corporations must act	6

*These 4 categories come from the conceptual framework of the NEXUS FUTURES research project. During the evaluation, further sub-categories were developed to make the evaluation of the 112 assumptions even clearer. For the sake of simplicity, these have not been presented here.

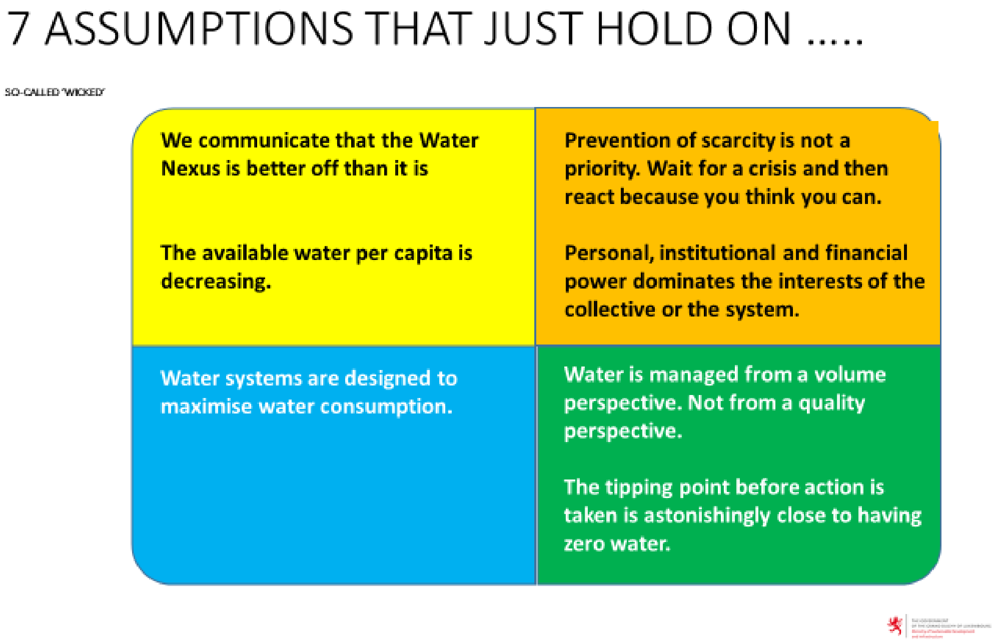


Figure 4.6 Assumptions from the international case studies that caused non-sustainable water use

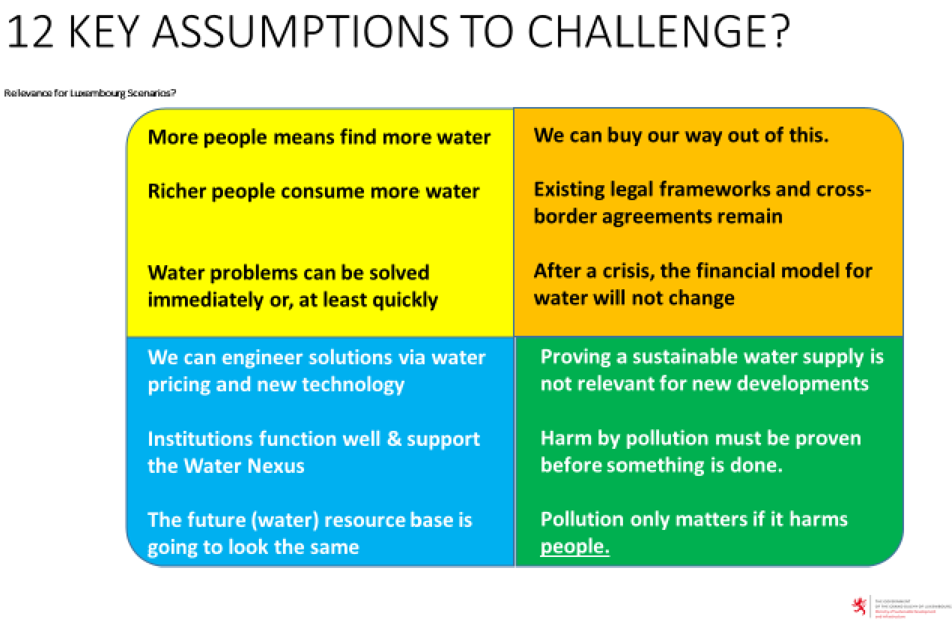


Figure 4.6 Assumptions from the international case studies that caused non-sustainable water use

10 Top Unknowns from Workshop 2 World Café:

- State of water bodies and water resources
- State of forests/biodiversity
- Climate change
- Population growth and migration

- Education, awareness and appreciation
- Health issues
- EU-Luxembourg Legal framework
- Participatory governance
- Data and knowledge for (political) decision-making - what is legitimate?
- Land use - availability
- Technological developments/innovation
- Economic development

Drivers of change

From interviews and a workshop session we developed an understanding of the likely main drivers of change in how we engage with water and land in the future. In the three scenarios these forces, played out very differently

.

Distribution of power and role of the state

What role do great powers like the USA, Russia, or China play? Are important resources, such as energy and water, controlled by a few people or are they managed in a decentralised manner? Are there more wars?

It is likely that the state budget will need to be fundamentally restructured due to growing deficits. This also changes the role of the state. The coronavirus pandemic in the early 2020s was / is just the beginning of a long series of new and unexpected demands on the welfare system. The precise ways in which government revenues and expenditures were restructured, and who gained or lost influence as a result. In these ways the three scenarios differ sharply from each other.

World trading system and economy

Will global free trade agreements still apply in 2045, or will the economy be organised more regionally? What values are reflected in prices and production methods? What is the relationship between the economy and the government?

What is certain is that a circular economy will emerge in which material flows are increasingly networked and less waste is generated. But what is going on behind the scenes in this economy? According to which principles are salaries and jobs allocated, prices and values determined, and decisions made? Here the three scenarios depict very different developments.

Technological innovation and the role of science

Which ethical principles are technological innovations subject to? Towards whose needs is innovation oriented? How close to nature are new approaches to solve supply problems?

Will smart technologies increasingly take over decision-making? And is new knowledge about promoting sustainability increasingly generated locally together with scientists, companies, and citizens?

It is very likely that we shall be virtually networked to an even greater extent and that artificial intelligence will play an even greater role in how we think and act. How exactly the roles are divided between people and learning machines in business and society depends, however, on the respective value systems; these are very different across the three scenarios.

Social structures and values

How is our society made up - in Luxembourg and Europe? Are new forms of community emerging, virtually networked, regionally, or locally in municipalities? How do we spend our free time? In citizens' groups, associations, families or alone? How much free time do we have anyway? And what makes life worth living?

One thing is certain: immigration will continue to diversify society. But how will Luxembourg deal with it? Open or selective?

Changes in the environment

To what extent will natural disasters, environmental pollution, and scarcity of resources limit options for action?

The potential impacts of climate change play out similarly across the three scenarios. But in each world, society is organised in a different way and its infrastructure is different.

The increase in extreme weather events such as heat, storms, and drought as a result of climate change therefore has different consequences.

The underlying assumptions in the scenarios on changes in temperatures, occurrence of extreme weather events and changes in the length of the hydrological winters are found in an expert contribution by Dr. Andrew Ferrone, head of the Luxembourgs meteorological service and Luxembourgs representative to the international Panel on Climate Change (Expert Contribution). According to this study, the Climate change attributes for Luxembourg that are shared across all scenarios are:

(i) a rise in average temperatures of a øT: +0.9°-1.2 C compared to 1980-2010 and greater seasonal variations of temperatures across the year associated. Notable consequences include an increasing risk of damaging heat periods in summer.

(ii) changes in the seasonal distribution and occurrence of extreme weather events, including torrential rainfalls and tornados, as well as summer droughts. Consequences include agricultural risks to harvests (crop damages, reduced numbers of pollinating insects due to water lack), ecosystem damages and collapse, increased run-off of surface water to rivers and the sea with less retention on land and in soil and less replenishment of ground water. Σ rain:-10% in summer: between -3% -+2% all year +5% in winter Strong rain: “17-23 days

(iii) the shortening of hydrological winters due to a rise in average temperatures will reduce the likelihood of snow leading associated with water infiltration and effective replenishment of groundwater bodies. Insects and disease vector propagation are favoured in shortened hydrological winters.

A bit of differentiation may be achieved by portraying these tendencies as more or less pronounced, and by placing the main focus of each scenario on a different set of adverse impacts of climate change. The smart world could wrestle with extreme weather events (ii) leading to flooding and fast runoff, to show what infrastructures and technical solutions might help and hinder flood risk management. A part of nature suffers particularly strongly from a high number of days above 40°C (i) and summer droughts, impacting the food system and ecosystems. In the common good scenario, the shortening of hydrological winters is emphasized, and impacts are placed in the spot light, with impacts on less groundwater replenishment in winter.

The NEXUS FUTURES Scenarios – content

From participatory work a scenario framework evolved – three different futures in terms of:

1. Prevailing values as ordering principles for attribution of resources and attention
2. Different mechanisms for social coordination
3. Different prevailing ontologies and associated understandings of science and its role in governance processes

The less specific essence, but one that is easy to work with and from which trade-offs can be discovered in diverse groups:

1. A technocentric/materialistic/objectivist world
2. An anthropocentric idealist/social constructivist/subjectivist world
3. An eco-centric / and somewhat ecostalinist /interactionalist world with a systems view on life

There are for example clear trade-offs between:
- Technological progress in a technocentric world ensured high levels of comfort for those who can afford it for this with access and voice and distributional issues.
- Distributed responsibilities, decentralisation, and empowerment led to the decline of reliable centralized structures and infrastructures for secure provision
- Dedicating the time and resources required for regenerating soil, water quality and biodiversity in diverse ecosystems managed or unmanaged by humans – vs personal freedom and rights to decide over private property… etc. primacy to activities to regenerate ecosystems vs. infringement on individual rights over private property, and personal freedom of choice

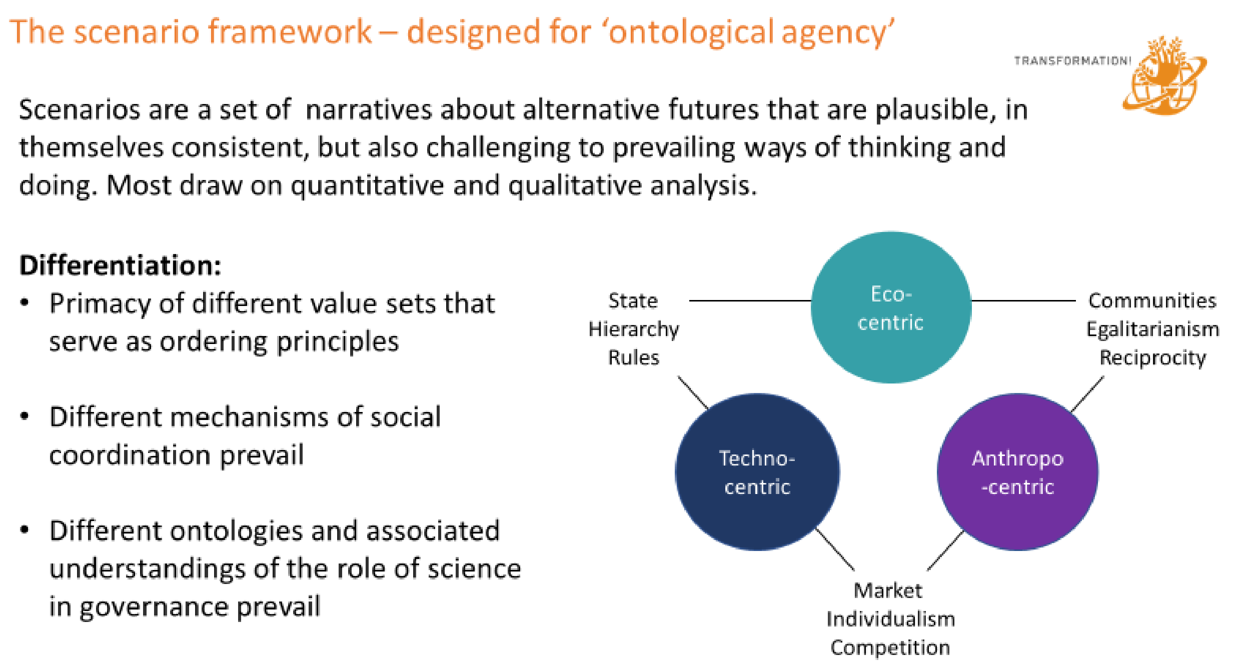


Figure 4.7 The scenario framework – designed for 'ontological agency'

Smart sustainability

The Smart Sustainability scenario is characterised by globally coordinated and rapidly advancing technological innovation. Prosperity is driven by economic growth and consumption. Online transaction taxes constitute the main source of public revenue. Around the world, economic and political interests function together like clockwork. They are the motor of a global economy that aims to reduce material flows and waste through technological innovation. Large multinational companies largely shape the fight against climate change themselves as a result of environmental rules and regulations such as emissions trading. Artificial intelligence and learning machines control a wide range of economic and social domains, subjecting them uncompromisingly to the dictates of efficiency. Amongst the 1.2 million inhabitants of Luxembourg, experts in energy, material flows and industrial design enjoy considerable influence. Amongst the rest of the population, convenience and dullness dominate.

Inequality in incomes and opportunities are also growing rapidly, whilst the costs of water and food rise steadily. Resource-saving technologies are thus not available to everyone.

Technological progress, driven by competition, marches on; many people - and nature – get left behind.

Smart spatial planning
Increasing population and economic activities are inexorably driving the construction of ever more homes, offices and industrial plants. The sealed land area is growing by 0.5 hectares per day; areas of housing and roads continue to expand, increasingly displacing forests and arable and undeveloped areas. Five 'smart' highly digitalised development centres, which are particularly important for economic development, have emerged. 432,000 people live there, that is 37% of the population. Access to high-speed internet varies greatly across geographical locations and is mainly concentrated in these centres. There are also ten other development centres, in which a further 30% of the population is concentrated. Most jobs and shops are also located in the cities, particularly in Luxembourg City. They are all close to the city, meaning that urban sprawl has increased greatly.

Engagement with water

Luxembourg's ecosystems are more fragmented than anywhere else in Europe.
The increasing water consumption and other ecosystem services such as the breaking down of pollutants, water retention and the maintenance of healthy populations of pollinating insects, are becoming a challenge.

Although with the help of new technologies water is being used more efficiently in both households and industry, the average water consumption per day in Luxembourg with 1.2 million inhabitants is 180.000 m^3/d, corresponding to 145 l per person per day. In summer, consumption can reach 200 litres per person per day (savings thanks to technology amount to less than < 10% per person). Taking care of water in everyday life is not a priority. As a result, all sewage treatment plants need to be better equipped, for the treatment and elimination of micro-pollutants.
Much of the water in Luxembourg comes from the Upper Sûre (Sür) reservoir. Some springs have also been made usable; however, these only cover 10% of consumption.

Water sources:

- SEBES provides: > 41 000 m^3/day (as of 2022)
- Additional sources restored for use: 5 000 m^3/d

Challenges:

- High, and poorly differentiated water prices and households subsidising industry increase inequalities
- High volumes of surface water increase environmental impact
- Micro- and nano-pollutants increase faster than treatment options

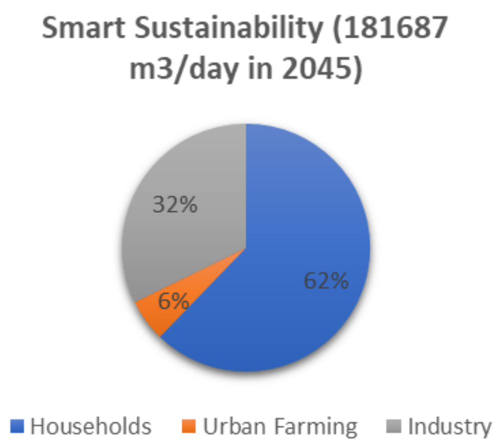


Figure 4.8 Projected water consumption in the 'Smart Sustainability Scenario

In sum, expensive technological fixes will be needed, therefore water cost leaps up, inequity grows:

- Declining soil quality and loss of biodiversity reduces nature's capacity to filter water, break down pollutants and retain water.
- The volume of micro and nano pollutants is increasing rapidly. New technologies for water purification need continually to be developed. This also leads to water price increases.
- High levels of water extraction from the natural environment and changes in the seasonal distribution of precipitation further increase the burden on ecosystems.
- Ever increasing and insufficiently differentiated water prices for households subsidise water prices charged to industry. This is one of many factors helping to cause rampantly growing inequalities.

State of the biosphere

Although much capital is being invested in infrastructure and production processes to regenerate renewable resources such as water and soil, in 2043 ecosystems will continue to be threatened and biodiversity across western Europe will continue to decline. The condition of forests and grasslands, along with the roots and soil life that plays a central role in the retention and purification of water and soil, continues to deteriorate: now only 10% of all trees in forests are in good phytosanitary condition, compared to 28% in 2016 and 77% in 1980. Farmers have become landscape stewards and are responsible for a complex system of monitoring and environmental accounting, also supported by GPS-linked, data-collecting tractors and 'input-output' calculations of material flows in farm accounts. This data system feeds both national statistics but can also be broken down locally to any scale to make statements about conditions for the optimal flow of environmental services. Despite all efforts to increase efficiency and close material loops, significant population growth in Luxembourg and a further increase in economic activities - also enabled by these very efficiency gains - rebound effects cause an increase in water pollution, forest dieback, soil degradation and air pollution.

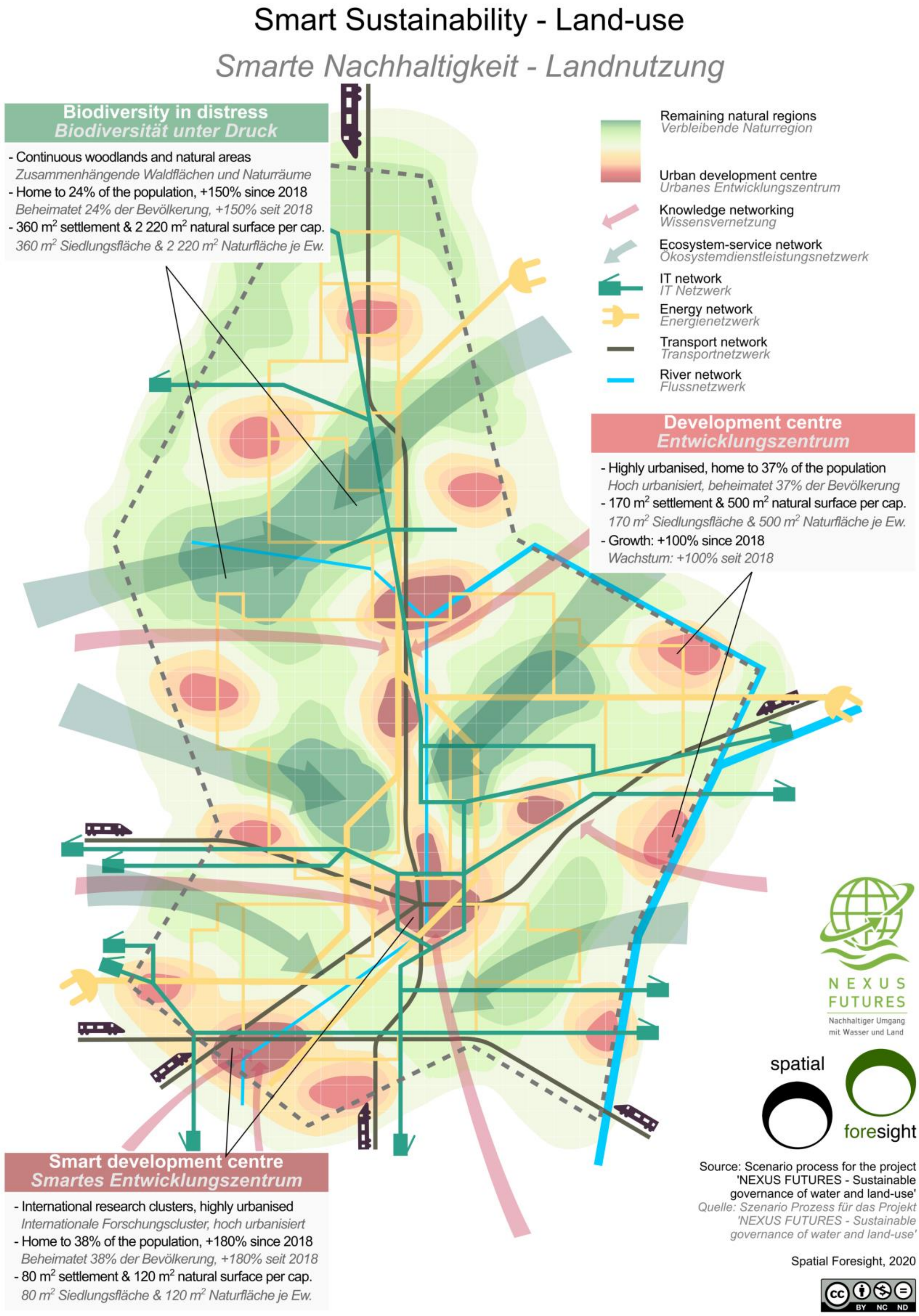


Figure 4.9 Land use in the 'Smart Sustainability' Scenario (Source: Spatial Foresight, Expert Contribution)

Common Good and Knowledge Scenario

In the “Common Good and Knowledge” scenario, regional initiatives largely replace the world trading system. As a result of budget deficits, governments are less and less able to provide infrastructure and welfare services for the population. This also applies to water and energy supplies. In addition, national pension, health, and education services are augmented by regional initiatives - often supported by volunteers. Most hospitals and schools are also regionally organised. Luxembourg is split into five regions, which have grown from fusions of existing groupings, in areas like water supply and waste disposal. The contributions of committed citizens, compensating for failures of supply at a time of crisis, are also essential for their well-being. The widespread introduction of local currencies (like the Beki in Beckerich in 2013) have stimulated the development of healthy regional economies. For most of Luxembourg's 930,000 residents, personal well-being resulting from dignity and security - data protection for example - are a priority. Local political participation is also an important aspect. The motto is ‘Greed is bad for you’.

Spatial planning

It has been realised that ensuring good nutrition requires healthy soils, biodiversity and local water sources. Regional resources are highly valued, and their use is optimised. Local cohesion is growing. However, differences and rivalries between regions are on the increase. National, centralised infrastructures are neglected; they fail ever more regularly. The inhabitants of Luxembourg are spread across five semi-independent regions, which are based, amongst other things, on historically developed groupings of water suppliers and on the natural borders of river basins. Some of these regions also extend beyond the national borders. Some regions cooperate in the supply of ecosystem services such as drinking water and food production. As an example, Luxembourg City depends on the surrounding areas for water and energy supplies.

For the most part, however, the rivalries between the regions are growing and urbanisation is primarily concentrated in five centres. Around 15% of the population live in each of the north, east and west of Luxembourg, and in Luxembourg City, respectively. The south is by far the most densely populated with 40% of the population. The sealing of soil related to urban development has however not increased in years.

Companies that recycle and reuse products and waste, as well as repair centres and local value-adding production facilities, form the economic basis of a regional circular economy. This is mostly based on cooperatives in which every locally active citizen has a voice.

Engagement with water

Water treatment and use are organised at the river basin level. Luxembourg consumes an average of 160.000 m^3 of drinking water per day, corresponding to 170 litres per person.
Domestic water circuits are regionally adapted and diverse. Many larger towns recover nutrients from sewage treatment plants and use them to produce energy for example. River water obtained from riparian zones is used for agricultural irrigation - especially during the hot summers. The Upper Sûre reservoir is slowly becoming less important for the domestic water supply. Rainwater usage takes place on an informal basis - privately and communally - and is regulated either badly or not at all. In addition, many sources have been restored to use. These cover 25 percent of the demand.

Savings measures (?):

- Technological and behavioural: -25% / person

Water sources:

- SEBES provides: > 41 000 m^3/day (as of 2022)
- Additional sources restored for use: > 40 000 m^3/d
- Rainwater use, informal, private and municipal, little or no regulation.
- Moselle bank filtration/flows for agricultural irrigation.

Challenges:

- Neglect of key infrastructures
- Increasing water prices
- Regionally very different water prices
- High volumes of surface water increase environmental impact

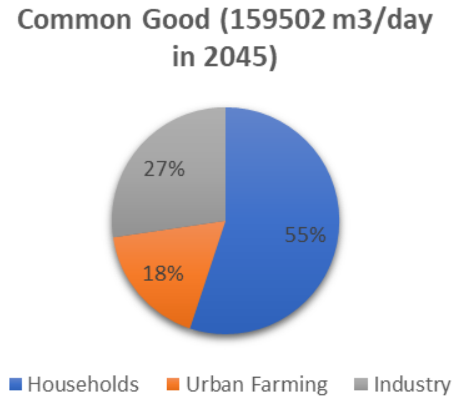


Figure 4.10 Projected water consumption in the 'Common Good and knowledge" Scenario

Summary:

- Restoration of local sources, therefore the demand drops, increase in water price, investments sink, infrastructure deteriorates and eventually fails
- Neglect of the infrastructure increasingly leads to burst pipes, the water supply is unreliable and prone to failure
- High levels of water extraction from the environment and changes in the seasonal distribution of precipitation are also increasing the strain on ecosystems
- Drinking water prices vary greatly between regions, creating tensions

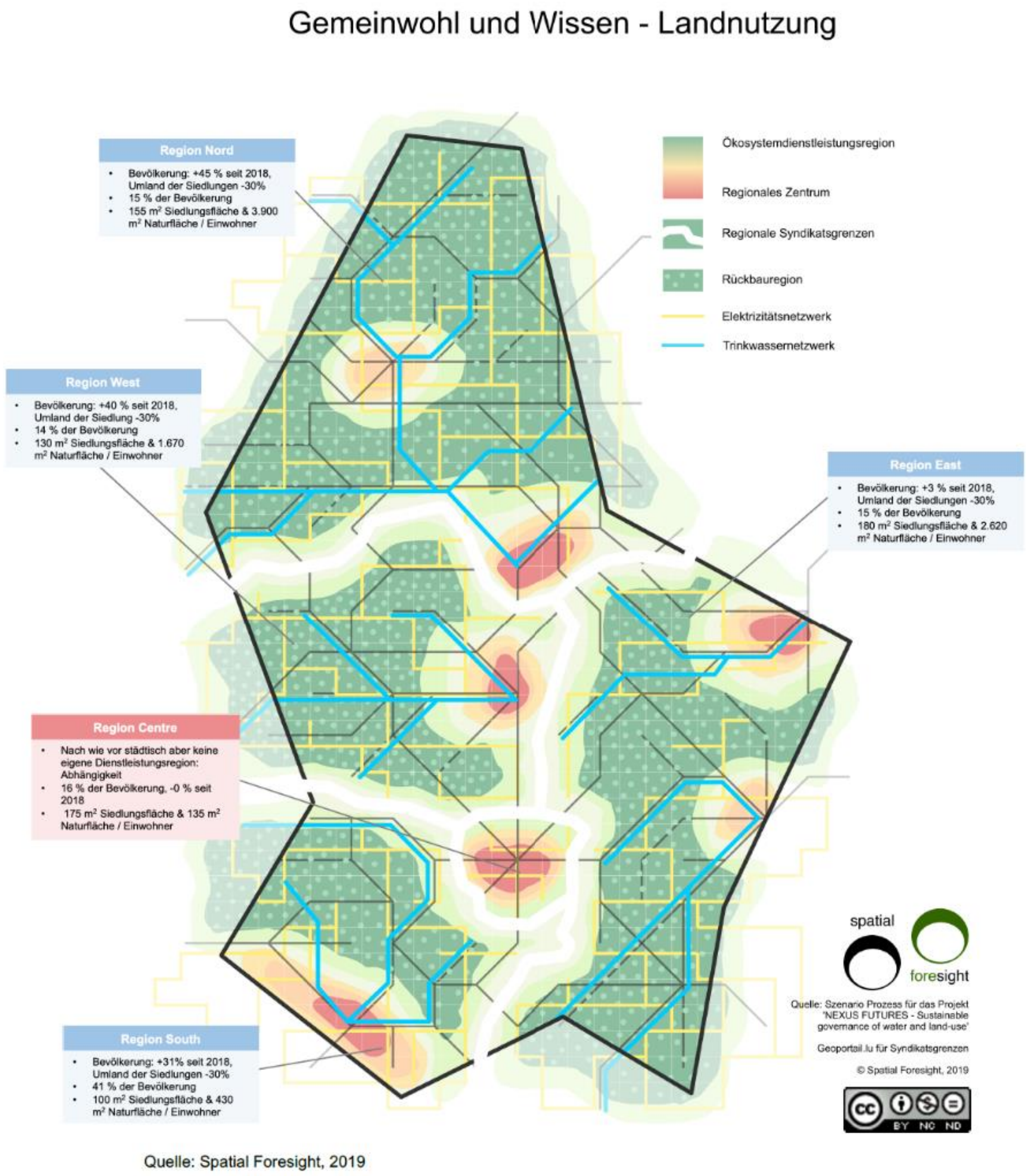


Figure 4.11 Land use in the 'Common Goods and Knowledge' Scenario (Source: Spatial Foresight, Expert Contribution)

Web of life

In the “Web of Life” scenario, regeneration of the environment is the priority, such that any right to free decisions about private property and personal development is increasingly undermined, despite the tensions that this creates within society.

Agriculture, environment, water, and spatial planning policies are closely interwoven and aim to ensure that every citizen can guarantee their own self-sufficiency, alone and in exchange with others. Everyone is thus prepared to face even the worst supply crises.

850.000 people live in Luxembourg, the green oasis at the heart of Europe.
With the ResilienceLux mobile app, every citizen contributes to the flow of data on the current condition of water, soil and biodiversity locally. So, everyone has a basis for making decisions about their own behaviour. This data also feeds into political decisions at the national level.

Most people are employed in the green finance and tourism sector, in the production of natural materials - for example for the construction sector - and in the manufacture of technologies for the reduction of pollutants. The design criteria for most products, manufacturing processes and services include contributions to biodiversity regeneration and carbon storage. Meanwhile the construction sector in Luxembourg specialises in the recycling of old building materials, using 'Lego logic' amongst other things. Rubble is considered a folly of the past.

The high levels of taxation of goods and services, which are mainly handled by artificial intelligence and robots, fund an optional basic income in several EU countries, including Luxembourg.

The awareness of the importance of biodiversity for securing human livelihoods defines the forms of innovation and progress. The maintenance of complex urban and rural ecosystems with high levels of biodiversity is however the most time-consuming activity of all.

In order to receive the basic income, individuals have to work at least 20 hours a week in regenerative activities. Examples of this include composting, the growing and processing of fruit and vegetables - including via agroforestry practices - shepherding and knitting clothes. A record of which of these activities are currently in demand is kept in a seasonally updated list.
A feeling of connection with animals and plants, light, air, and earth brings meaning to people's lives. Active participation in the rebuilding of a dense network of life makes it easier to forego highly valued former freedoms and a high degree of individuality.

Spatial planning
In this scenario, a central inhabited band stretches along the Alzette river, which connects two metropolitan areas called Nordstadt and Südstadt with the capital. It is home to almost 90% of the population, around 750.000 people. Communities and business locations are crowded into this band. Investments in an integrated energy, information and water supply network have been concentrated there for decades.

As a result of a large number of wildlife bridges and renatured river sections and roads, this area appears less densely populated than it actually is. A transport system including a monorail and well-equipped public transport limit the environmental impact of mobility. Traffic options for cyclists and pedestrians between Luxembourg City and the surrounding country areas have been greatly improved. Apart from a few exceptions, cars are not used in the central band.

Garden areas interwoven with agricultural areas, flank the inhabited band. Soils have been revitalised through agroforestry practices, permaculture, and intensive enrichment with compost. There are also allotments available to citizens on the basic income, for their own production. In the rural zone beyond this area, only limited transport and supply systems are maintained. Water and energy are thus much more expensive there.

A "wild area" extends beyond the garden area in the east and west of the country. It is mainly used by itinerant shepherds and their sheep and goats. There are only a few cattle left, as people's meat consumption has been greatly reduced. There are a few scattered areas allowing for simple forms of nature tourism.

Engagement with water
Waterbodies have been regenerated and are protected. The use of surface water from rivers and springs is kept to a minimum. The average daily per capita water consumption is 125 litres.

Flows of water and nutrients are organised in biological cycles. Water for technological and industrial purposes is expensive and its supply is combined with district heating or cooling in closed cycles. The use of rainwater – both private and municipal - is strictly regulated. In addition, some natural water sources have been returned to serviceability.

Water prices are seasonal and vary according to volume with thresholds above which price increases are steep. Drinking water is more expensive than industrial water. There are different circuits for different levels of purity and whether it is an industrial or natural water cycle.

Savings measures (?):
- Technological and behavioural: -38% (125l) / person

Differentiated Water cycles (technological and biological)
Water sources:
- SEBES provides: > 41 000 m^3/day (as of 2022)
- Additional sources restored for use: > 30 000 m^3/d
- Rainwater use, formalised with limits; private and municipal

Challenges:
- Little freedom, much control
- Complex and time-consuming management system – participation through citizen science
- High water consumption for cultivation and local vegetable production
- Nature is recovering

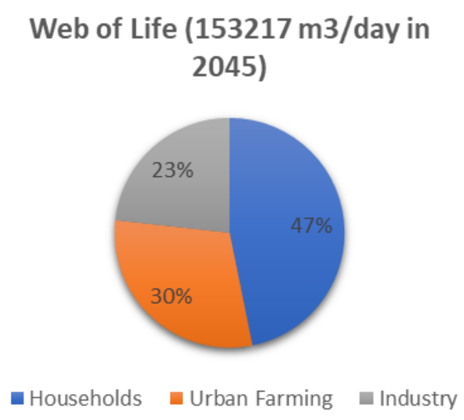
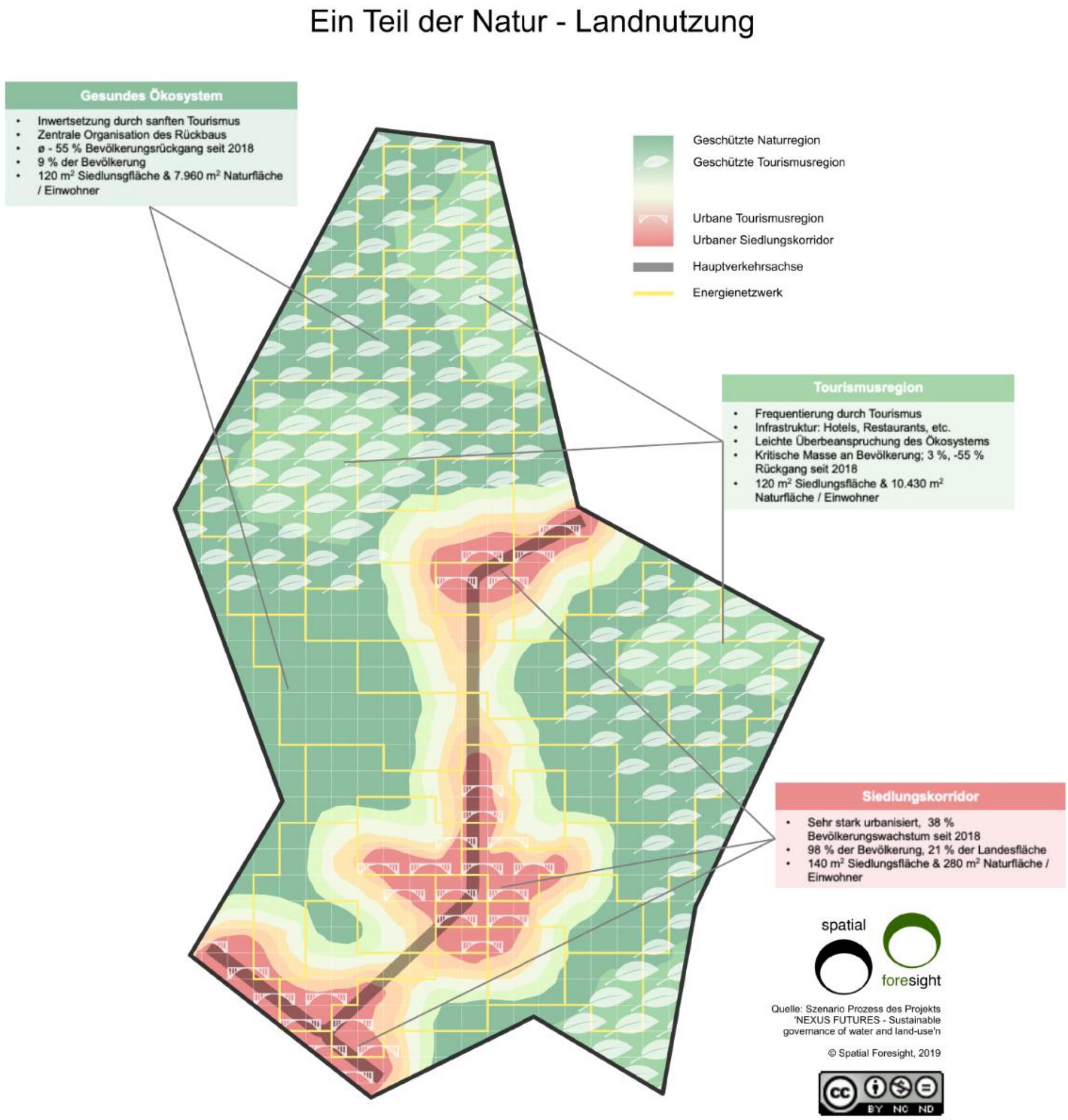


Figure 4.12 Projected water consumption in the 'Web of life" Scenario

Summary:
- Local vegetable production – especially for personal use – consumes a lot of water
- The use of water is regulated by a complicated management system, based, among other things, on citizen participation in data collection
- Surveillance of one's neighbours is widespread
- Ecosystems are recovering, but at the expense of human freedom



Quelle: Spatial Foresight, 2019

Figure 4.13 Land use in the 'Web of Life' Scenario (Source: Spatial Foresight, Expert Contribution)

Conclusions on the scenarios and their further use

The three very different scenarios offer a new systemic framework for future-oriented planning discussions with various interest groups. They offer a way to find less bureaucratic ways of implementing locally adapted measures concerning how we deal with water and land. The scenario set shows how various values such as efficiency, the common good and our relationship to nature, contribute to determining our future. These values do not only provide a direction for innovation. They also determine which ideas about “progress” and “the good life” shape the intentions and actions of individual citizens and organisations.

The scenarios illustrate different developments in terms of scope for action for different actors and trade-offs - How much water is needed and by whom? - What is the water demand, how is it distributed and shaped, what kind of water is needed (e.g. differentiation of treatment)? - Where does the water come from? Main areas of tension between developments in society, technology and the environment that play out in very different ways: The use of surface water (and groundwater) vs. pressures on ecosystems-water treatment, water pricing, access, regional/municipal autonomy, distributive justice, etc. One main challenge is: Little space/time to present - what do you think should be emphasised and how should it be presented as a good basis for discussion e.g. about changes in communities, companies and politics?

In particular on water, the quantitative modelling suggests that Luxemburgs water availability (from 2030 onwards) will be a limiting factor for population and economic growth (It is likely that there is security of supply until 2028-2029 provided that the new SEBES installations are completed on schedule.[6]) With an increase of 12500 persons/year, an average of 2500 m^3/day, with peak consumption 3750 m^3/day will have to be found mostly in summer. These circumstances are already relevant today.
There is need for initiative to:

1. How much water do we use? Introduction of water saving measures, technological and behavioural
2. From where to we obtain water? (Re)assessing all available sources and amounts of storage available for "peak shaving" is urgent

1.250.000 inhabitants could theoretically just about be supported. Early planning, adequate funding, consumer participation and (improved) legislation will be key factors for success.
Climate change impacts can destabilise Luxembourg's water supply at peak times.

- Opportunities and uncertainties for our adaptation to climate change are not only in the areas of technology, infrastructures, and the natural environment.
- New approaches to understanding complexities and learning how to deal with them require new place-based governance, and both technological and social innovations.
- Participatory and value-based meaning work is needed. What does this mean for us, what changes make sense here and now?

It is imperative that action is taken soon to initiate water saving measures and a (re-)evaluation of any available sources and storage volumes available for peak shaving is recommended. Generally, expanding the knowledge of the actual and future situation would be advantageous (data availability, modelling). After 2028-2029, at current growth rates without water saving, it is likely that water availability will be a limiting factor for population growth. Finally, the limited analysis done in this report clearly shows that there is a real potential that climate change could destabilise Luxembourg’s water supply during peak demand times (up to 180.000 m^3/d in 2045).

Furthermore, the spatial planning scenarios were motivated from the fact that closer analysis of goals and targets set for example by the working groups of the process of the Third Industrial Revolution placed competing demands on land parcels across Luxembourg. These contradictions were resolved by differentiating three spatial planning scenarios each of which gives primacy to a different set of values.

[6] Expert paper 2. An overview on work in progress on modelling water use for Luxembourg with reference to the three NEXUS FUTURES Scenarios for engagement with water and land in 2045 (
Dr. Alex Cornelissen1, Dr. Georges Schutz1, Dr Ariane König2)

A whole range of areas for action is becoming apparent, most of which are in fact already available to everyone today. They make it possible to promote distributive justice, to expand our shared intelligent networking among each other and to improve concepts of sustainable engagement with water and land.

However, it is also clear that the state of the Luxembourg water supply is not a dire as often predicted and that maintaining a functional water supply for the next 25 years will be challenging but not impossible even with a population of 1.250.000 in 2045. Early planning, proper funding, consumer participation and legislation will be the key ingredients for success.

We can use the scenario set together, to discern future-oriented areas of action for a sustainable approach to nature for ourselves and with others! The scenarios are particularly helpful when meeting with different interest groups to discuss a variety of concepts, views and evaluations of different options for action or developments, also with respect to existential risks that we would all wish to avoid. This can help with sharing practical knowledge so that we can cooperate to change the broader system within which we are actors.

There are many approaches to this in transformation research - for the localisation, design and consolidation of social learning processes, e.g. in real laboratories for resilience.

The scenario set was deployed in a workshop with municipalities (CIPU Workshop) on adaptation and mitigation of climate change. Working with municipalities to explore options with the NEXUS FUTURES Scenarios on 9.12.2020, with 15 Participants from Ministries, Administrations, Municipalities, (some ‘usual suspects’)

Evaluation questionnaire after the workshop:

- The urgency and need for transformative action is clarified through the scenarios. The narratives proved welcomed, shared reference points in the future as basis for dialogues between technical staff, implementation oriented and strategic participants.
- Some individuals were prepared to stick their necks out on what may be thinkable and doable further than was observed in more conventional settings to discuss climate change adaptation. With reference to the scenarios as a safe space in the future, usual patterns of thought seemed to be extended if not disrupted.
- The different ontologies / belief system of the scenarios helped to illustrate trade-offs between prioritisation of different courses of action.
- Apprehension and prioritisation of – low hanging fruit…
- Good evaluation by participants, also in comparison to other CIPU Workshops

We also used the scenarios in a workshop as part of a participatory process to contribute to the development of a national strategy on agroforestry.

We also propose to use the scenario sets in short workshops with relevant inter-ministerial groups, such as the one working on the sustainability check for companies, or the inter-ministerial group on climate change adaptation and mitigation. Further ideas for useful applications for the results could also emerge from a meeting with the inter-ministerial group on climate policy.

6. Conclusions and next steps

In sum, the project can be seen as one of the first transformative science projects in Luxembourg that started to address research questions relating to more effective decentralized and transformative governance processes and the nature of the evidence base that can serve these to regenerate the life support system constituted of healthy water, soil, and web of diverse life forms in Luxembourg. Concrete tool sets were developed in the form of a citizen science toolset to engage volunteers in participatory processes to better understand, collect empirical evidence and act upon issues relating to water quality. The main objectives and deliverables set out in the Convention between the MECDD and the University of Luxembourg on the NEXUS FUTURES project have been met.

The NEXUS FUTURS Project was also designed to serve for capacity building at the University of Luxembourg and amongst interested stakeholders for engagement in future-oriented research on complex dynamic social-ecological-technological systems considering the energy-food-water nexus in Luxembourg.

Several interviews and workshops conducted in the frame of the project suggest, that given increasing evidence on degradation of water quality and land, and healthy ecosystems, the urgency for effective action is increasing. The growing number of actors who recognise this also recognise that the prevailing governance processes may be too slow or not effective enough to bring about the necessary changes in a reasonable timeframe. This stands in direct tension to the challenges towards more decentralized or polycentric governance above.

Challenges to more decentralized and transformative governance approaches that rely on decision-making processes informed by participatory action research that could be crystallised out in this research are manifold and include:

- National state actors expectations of certainty, command and control based management
- Knowledge asymmetries
- Conflict aversion
- Pressure to avoid failure
- Desire and pressure for efficient processes
- Heavy reliance on pre-defined accountability regimes
- Participation fatigue and – attention to the dark side of transformations – are those expected to participate including more marginalised groups attributed resources and compensated for time to do so?
- Tension between simplification conveying certainty and complexity becoming inaccessible

We will in our future projects seek to tie together these work-strands by developing a Luxembourg Transformation Laboratory for regenerative engagement with water, soil, and the web of life. A web platform offers access to a site in which individuals can easily enter information on sustainability initiatives across diverse sectors is being developed and will foreseeably be launched in September 2022.

Figure 5.1 The Transformation Lab Luxembourg
The (currently in German) button "Mitmachen" leads to the mentioned sub-site, enabling all users to share their initiatives on sustainability to share and learn with/from other change agents. "Wissenschaft" (Science) leads to a data collection of scientific initiatives and research on sustainability in and around Luxemburg. "Fortbildung" (Training) offers a variety of opportunities where motivated stakeholders and private individuals can look for education programs related to the energy-food-water nexus.

The main objective of our transformative science research projects will remain to better link diverse actors across policy sectors, levels of governance, places sectors of society, - create spaces for place-based experimentation and link these initiatives together in a learning network. A virtual place allows to link different participatory engagement processes and experiments that are place based, across time and space and to allow for cross reference, cross analysis and networked learning and joint evaluation with diverse stakeholders.

Future strategy and vision

The increasing pressure on land and the life support system in general, and more specifically from a wide range of adaptation and mitigation measures relating to climate change are of increasing concern nationally and internationally (IPCC, 2019).

A five-year follow-up project with a focus on drought resilience with a citizen science-based early warning system has just been secured. The aim is the development of a drought early warning system to predict water supply shortages in Luxembourg. The project will also involve participatory action research with the systems main users: besides farmers and municipalities, administrations (e.g., AGE, ASTA, ANF ...) and private companies (e.g. RTC4Water) should also be involved. The focus will be on recognizing and acting on risks of agricultural droughts, as well as informing drinking water providers. The system will rely on remote sensing data with local crowd-sourced data with citizen science (e.g., soil moisture, vegetation cover).

Furthermore, our research group was engaged in a pilot project by the Administration de la Nature et des Forêts (ANF) to co-create a national strategy for agroforestry for a more climate change resilient food system that provides more structural components for diverse habitats, and we will seek funding to build a larger five-year project to develop an impact assessment approach for citizen science projects that is tied to first pilot projects of agroforestry in Luxembourg. The citizen science tool kit can be expanded in future to include other variables for environmental data collection, such as soil quality for community gardening initiatives, and other parameters. This tool as well as the research insights on the water-food-energy nexus interactions in Luxembourg could also become the basis for developing teaching materials for future-oriented systems thinking in executive training programmes and schools. Both topics emerged as priorities from the national scenario process. They will be pillars of our national Transformation Lab that we will launch with our partners in government and NGOs in summer 2022.

Organisationally, in the medium to longer-term, the aim is to continue to build our team to stabilize the number of members at about 10-12 researchers with qualifications across diverse disciplines in the natural sciences, social sciences, and humanities. A larger team is also necessary as participatory research is particularly time intensive as the success rests on building high quality relationships. We need additional capacity to engage nationally as well as in international research projects.

The plan is to dedicate at least the next 10 to 15 years towards further facilitating the establishment of innovative structures and practices for evidence-based learning in cross-scale participatory processes for the regeneration of the life support system through place-based action and policies in Luxembourg. We plan to extend these activities internationally with our network of partners. We hope thereby to contribute to complementing current democratic processes in a way that promises more differentiated responsiveness across multiple levels of governance, different situations across different locations in turbulent times in the 21st century, compared to current largely technocratic expert-based regulation that prevails in the EU.

Annex 1. List of deliverables and dissemination activities

The transdisciplinary research and teaching approaches rely on collaboration with partners from public bodies, organized civil society and private sector enterprises. On one hand, continued collaboration and exchange with officials and practitioners inform my research and teaching and ensure appropriate framing of research questions for salience and to address real problems in practice. Exchanges with practice partners help direction setting and deciding on the evolution of contents and focal themes. On the other hand, working with these experts in turn also helps to legitimate to our findings and methods, and to increase chances that they gain traction in practice. Last but not least, partnerships with public bodies and active involvement in advisory committees, and our interactive research style aiming at dialogic learning by all engaged in interviews and workshops, allow to contribute insights from my research, and to engage in capacity building in scenario and systems approaches and future-oriented systems thinking in practice with professionals.

Work with private partners and consultancy activities

As part of the NEXUS FUTURES Project, we outsourced contributory expert studies (2019-2020) to three private partners whom we also regularly invited as lecturers in the study programme. We collaborated with the following firms:

- RTC4Water providing technical services and a tool set with artificial intelligence controlling water sourcing and tanks for improved water management at the level of municipalities. Together we developed a quantitative modelling approach for different scenarios for water use and provision. This collaboration will continue in the frame of the new five-year project on drought resilience and a new focus on trying to estimate water use and distribution in the context of the technological and natural hydrological cycles across Luxembourg's six main river basins.
- The private consultancy Spatial Foresight on three different spatial planning scenarios for Luxembourg, which help to illustrate the pressure on land from different needs and contradictions between related policy fields.
- The private consultancy +ImpaKT on different scenarios for the circular economy in Luxembourg in 2045 adapted to the differentiated three scenario set.
- Citizen Science on water quality – the Waterblitz events: in 2019 and 2021 doctoral candidate Karl Pickar and I organized two large sampling campaigns with a citizen science tool in collaboration with the NGO Earthwatch,'s subgroup Fresh Water Watch (FWW). There was significant media coverage both times (Luxemburger Wort, Télécran, Radio 100,7, amongst others), in 2019 we had over 100 engaged volunteers collecting and analysing water samples. In 2021 we had just under 300 (296) volunteers.

Scientific publications (co-authored)

Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martín-López, B., Hondrila, K., König, A., von Wehrden, H., Schäpke, N. A., Laubichler, M. D., & Lang, D. J. (2020). A pluralistic and integrated approach to action-oriented knowledge for sustainability. *Nature Sustainability*, 1–8. doi:10.1038/s41893-020-00616-z

Hondrila, K. (2021). Actionable knowledge and social learning for sustainability. Ph.D. Thesis. University of Luxembourg.

König, A. (ed.) (2018). *Sustainability Science: Key Issues.* Routledge.

König, A., Pickar, K., Stankiewicz, J. & Hondrila, K. (2021a). Can citizen science complement official data sources that serve as evidence-base for policies and practice to improve water quality? *Statistical Journal of the IAOS* 37: 187-204. DOI: 10.3233/SJI-200737

König, A., Ravetz, J., Raber, B., Stankiewicz, J., Rojas-Aedo, R., Hondrila, K., and Pickar, K. (2021b). Taking the Complex Dynamics of Human–Environment–Technology Systems Seriously: A Case Study in Doctoral Education at the University of Luxembourg. *Frontiers in Sustainability* 2: article 673033. doi: 10.3389/frsus.2021.673033

Luederitz, C., Schäpke, N., Wiek, A., Lang, D.J., Bergmann, M., Bos, J.J., Burch, S., Davies, A., Evans, J., ; König, A., Farrelly, M. A., Forrest, N., Frantzeskaki, N., Gibson, R. B., Kay, B., Loorbach, D., McCormick, K., Parodi, O., Rauschmayer, F., Schneidewind, U., Stauffacher, M., Stelzer, F., Trencher, G., Venjakob, J., Vergragt, P. J., von Wehrden, H and Westley, F.R (2017). Learning through evaluation - A tentative evaluative scheme for sustainability transition experiments. *Journal of Cleaner Production* **169**: 1-16. doi: 10.1016/j.jclepro.2016.09.005

Pickar, K. (2022). Exploring the potential of citizen science to contribute to water governance. Ph.D. Thesis. University of Luxembourg.

We are at present engaged in writing a series of at least three further papers based on the empirical data from our research projects funded between 2017-2021. The pandemic has slowed down our team considerably as most of us have children and repeatedly spent unexpected time at home. For more information on the projects, please visit our website (https://transforamtion-lab.lu/).

Scientific conference presentations

Caniglia, G., Luederitz, C., von Wirth, B., Hondrila, K. (2018), discussion session on “Knowledge and evidence in transition experiments: Addressing an open question in theory and practice”, Internat. Sustainability Conference, University of Manchester

Hondrila, K. & König, A. (2017), poster presentation on “Actionable knowledge: developing an analytical framework for tackling water-land use challenges in Luxembourg”, International Transdisciplinarity Conference 2017, Leuphana University

Hondrila, K. & König, A. (2021), “Fostering actionable knowledge for sustainability via social learning: roles of professional knowledge and narratives”, International Transdisciplinarity Conference, Zürich (online)

König, A., Hondrila, K., Manhart, S., Pickar, K., Raber, B., and Sebastian, I. (2019). Collaborative Conceptual Systems Mapping (CCM) and its potential for transformative dialogue. Presentation in Session 2-4 on collaborative methods. International Leverage Points Conference at the Leuphana University from 7-9 February 2019.

Hondrila, K. & König, A. (2019), “Leverage points and actionable knowledge: conceptualising relations”, Leverage Points 2019: international conference on sustainability research and transformation, Leuphana University

König, A. Member of expert panel on ‘UN Sustainable Development Goal 6 on Water’ at the 2018 October Days for Sustainable Development at the European Investment Bank and EIB Institute on “Financing the SDGs”. on 11 October 2018.

König & Stankiewicz (2021). 30. Wissenschaftliches Kolloquium der Deutschen Statistischen Gesellschaft 'Von der Umweltstatistik zur Nachhaltigen Entwicklung. We contributed a jointly prepared presentation on the potential of citizen science as data source for official statistics with Dr Jacek Stankiewicz on 19.11.2021

Pickar, K. (2019). CitSci Konferenz in Raleigh, USA, Lightning Talk on Co-Design-Workshops for Citizen Science on 17.3.2019.

Stankiewicz & König (2021). Co-organisation and invited presentation at the **European Statistics Day** '**Workshop on non-traditional data sources and data science for official statistics'** organized by **the European Statistical Advisory Committee** that I am member of. Presentation on the potential of citizen science as data source for official statistics with Dr Jacek Stankiewicz, on 20.10.2021

List of all workshops organized or contributed to in Luxembourg

Luxemburg Kolloquium zum Weltwassertag 2021. Virtuelle Konferenz am 22.3.2021. Neue Ansätze zur Öffentlichkeitsarbeit mit Citizen Science und Reallaboren. Presentations by Kristina Hondrila and Ariane König and moderation of round table by Ariane König.

TEDx Luxembourg 2020: Talk on restoring the foundations for life on earth by Ariane König

König, A. (2020). Key note speech on Climate Action at the municipality of Junglinster Climate Crisis Conference on 10.12.2020.

König, A. (2020). Key note on 'Scenarios for climate resilience' at a Luxembourg workshop with municipalities at a workshop of the Cellule Nationale d'Information pour la Politique Urbaine (CIPU) on 9.12.2020.

3rd national workshop for the participatory development of national scenarios on engagement with water and soil resources, 29. January 2019 (33 participants).

2nd national workshop for the participatory development of national scenarios on engagement with water and soil resources, 29 November 2018 (35 participants).

1st national workshop for the participatory development of national scenarios on engagement with water and soil resources, 18-19 June 2018 (2 days, 37 participants).

Press coverage 2021

Télécran 28.4.21. pp. 12-13 Die Belastungen steigen.

https://gemengen.lu/web/2021/04/19/pour-une-gestion-durable-de-leau/

https://delano.lu/d/detail/news/lux-residents-called-contribute-freshwater-analysis/214356

https://www.wort.lu/de/panorama/die-wasserqualitaet-in-luxemburg-auf-dem-pruefstand-60897349de135b9236c9dcf6

Tageblatt-Artikel (website citizen science)

Interview auf 100,7 (https://www.100komma7.lu/podcast/267714)

Lectures or seminars at other universities at which the Luxembourg NEXUS FUTURES Project was introduced

2021-2022: An invited lecture course on 'Future-oriented systems thinking for sustainability', **Sophia University, Tokyo, Japan.**
January 2022: An invited seminar on transformative citizen science for transformative governance in the seminar on research methodology in geography in the Masters programme in Geography at the **University of Trier**.
2018 - 2021: Annual invited seminar and workshop on systems approaches for collaborative mapping of complex social-ecological-technological systems at the **University of Namur, Belgium**, in the Masters programme on 'Smart ruralities'.
2017-2019: Annual Invited summer school seminar and workshop (6 days) on systems approaches for sustainable campus development at the **University of Hokkaido, Sapporo, Japan.**
2018: Invitation as guest speaker on 'Developing transformative sustainability science in Luxembourg: Concepts, methods and practices' at the **Institut für Technikfolgenabschätzung und Systemanalyse / ITAS, at the Karlsruhe Institute for Technology** by Prof. Dr Grunwald on 16 January 2018.

Annex II. Expertise at the heart of this project – Brief Biographies

Post-Doctoral Researcher:
Dr Jacek Stankiewicz:
Having seen the fall on the Iron Curtain in Poland and the end of Appartheid in South Africa before turning 18 has left me with a profound conviction that inclusion of everyone in necessary for any project to be a success. Having started my studies in Mathematics and Theoretical Physics has given me a very strong foundation for a scientific career, but the relatively abstract nature of these disciplines left me feeling somewhat disconnected from the public. I therefore changed to environmental science, graduating with a PhD from the University of Cape Town with a thesis on the evolution of river networks and water supply in the face of ongoing climate change. I then fell back on my physics background to develop efficient earthquake early warning systems for developing countries in Central Asia, and then conducting research for a sustainable energy company in Luxembourg. Working on the citizen science component of the Nexus Futures project has for me a pleasure and a privilege, and in my view the project's success demonstrates the necessity for public engagement in all phases of a scientific project.

Principal Investigator:
Dr Ariane König
The experiences gained as regulatory affairs manager in a life science company defending science-based impact assessments of genetically modified crops in regulatory procedures in 27 different countries highlighted issues with current science-policy-practice interfaces and the need for place-based approaches in how we engage with water, land, and the web of life. These experiences still provide a constant 'reality check' when engaging with abstract academic concepts in the literature. Furthermore, my practical work experience at the interface of science, the law, politics and public acceptance in times of controversy, in the private sector and intergovernmental organisations has proven invaluable in designing our transdisciplinary research approaches such that they are engaging and potentially transformative for diverse participants who are active at different levels of governance. Other relevant past career experiences including diverse academic engagements, as well as work in a multinational corporation and with the OECD and EU institutions, provide a unique basis for such transdisciplinary research and teaching, that draws on diverse knowledge fields across the natural sciences, social sciences and humanities, and is embedded in practice and real-world policy-making processes. My academic work at the Universities of Oxford, Cambridge and Harvard, provides a solid knowledge base and critical mind set, and helped to recruit internationally leading researchers as advisors and lecturers.

Annex lll. Extracts from the Nexus Futures project proposal (2016)

The challenge: Unsustainably managed drinking water systems resulting from increasingly intense industrial, agricultural and recreational uses and pollution is threatening the secure supply of safe water for drinking and recreation. Accelerating and interdependent global and local changes in technology, society, economy and environment are undermining our current efforts of prediction and control. Moreover, climate change is expected to have regionally contrasted impacts on water resources, increased frequency of extreme weather events heightens flood risks, which may in turn destabilise agricultural production and certain forms of energy generation; this can in turn lead to price shocks in food and energy markets. Therefore, traditional disciplinary fields of 'normal' science and static approaches to management and governance relying on prediction, regulation and control can only play a limited role in resolving such complex problems. Instead, we need improved approaches for gaining a shared understanding in diverse stakeholder groups of interactions and feedbacks in complex dynamic social-ecological-technological systems as a common knowledge base for concerted action.

The policy and regulatory context: The European Water Framework Directive (2000/60/EC) recognizes that in view of the growing complexity new approaches to water governance and knowledge processes informing water use are required. The definitions of 'water quality' and associated standards now include a wide range of human considerations beyond science. The law requires involvement of stakeholders including citizens in water governance at the EU, national and local levels. Related Sustainable Development Goals of the United Nations and associated targets and measures adopted as part of the Agenda 2030 also invite innovative governance approaches based on new forms of collaborations between diverse stakeholders including public authorities, enterprises, research scientists and citizens. In Luxembourg, the EU Directive was transposed to national law in 2008 (Loi du 19 décembre 2008 relative à l'eau); it presents a legal basis for five river partnerships, in which stakeholders make contractual commitments to improve water governance (www.flusspartnerschaft.lu). Government plans for adapting and implementing Agenda 2030 are being drawn up. Vision 2020 of the European Statistical System calls for the generation of data and statistics from more diversified sources.

Goal: This project aims to engage stakeholders in river partnerships, policy makers, and experts on water and agriculture in co-designing a citizen science tool with an indicator set for participatory monitoring to create actionable knowledge for improved water governance; the broad use of this monitoring tool wil be promoted in river partnerships across the country. The participatory co-design process will be structured based on conceptual systems mapping and scenario approaches to direct attention to interdependencies between social, technological and environmental change in forward looking manner. During these processes stakeholders from private enterprise, organized civil society, and policy makers from relevant Ministries and public agencies, and experts collaborate to gain an enhanced and future-oriented understanding of the complex dynamic system they are embedded in. Each participating organisation can develop their own problem framings and approaches to address challenges. From observations across the disparate engaged organisations, socially robust recommendations for policy-making and systemic change at the national level can emerge.

Focus and scope: The project's main focus is 'The sustainability of the quality and quantity of ground water resources and nutrient flows in Luxembourg, in view of accelerating changes at the water-food nexus.' The scenario process will develop considerations on drivers of change and associated uncertainties relating to the water system and food production at the national level. The citizen science tool will be developed in a local collaboration with the river-partnership for the river Syre. The exact scoping of the system boundaries will combine geophysical considerations as well as social considerations and therefore will also be based on a stakeholder analysis (see research approach). After completion of this project the sustainability indicators system can serve as basis for a community-driven social learning process in this and other municipalities, involving a cyclical process for evaluation and adaptation of these indicators over time. A future research project can then assess and evaluate the potential of this sustainability indicator system for transforming human-environment interactions over time.

Project objective: The project aims to contribute to reconfiguring the science-policy-practice interface relating to the governance of water and food systems in Luxembourg. Of particular interest are likely system dynamics and feedbacks (unintended and/or by design). Developing approaches

and tools for participatory knowledge co-creation and social learning with experts, stakeholders and policy-makers will allow to identifying less-obvious blocks to and leverage points for sustainability transitions. More specifically, a series of workshops will serve to engage stakeholders in a river partnership, and policy makers and experts on water and agriculture at the national level in the **co-design a citizen science tool. The tool will be structured with an agreed indicator set for participatory monitoring** to create actionable knowledge for improved water governance. The broad use of this monitoring tool will be promoted in river partnerships across the country. The participatory co-design process will be guided based on **conceptual systems mapping and scenario approaches** to direct attention to interdependencies and feedbacks between social, technological and environmental change at the national level in forward looking manner. To gain understanding of complex system dynamics at different scales, the conceptual systems mapping workshops will be conducted at the local level in the river partnership of the catchment area of the river Syre as well as at the national level. During these
processes stakeholders from private enterprise, organized civil society, and policy makers from relevant Ministries and public agencies, and experts collaborate to gain an enhanced and future NEXUS oriented understanding of the complex dynamic system they are embedded in. Each participation organisation can develop their own problem framings and approaches to address challenges. From observations across the disparate engaged organisations, socially robust recommendations for policy-making and systemic change at the national level can emerge.

New approaches to combining *research, governance, and learning* in a systems and future-oriented manner with communities of public authorities, stakeholders and scientists are required in the face of accelerating and interdependent changes in technology, society, economy and the environment. This research project explores whether more sustainable water and land-use governance may be fostered by co-creating an approach for citizen science in Luxembourg.

This project will develop a citizen science approach using mobile devices coupled with detection kits for two major water pollutants: Nitrates and hazardous bacteria. In addition, data for collection can comprise sets of indicators for related and interdependent social, technological and environmental changes; all quantitative and qualitative data and photos entered via a mobile APP into a data base will be time and location tagged. The set of indicators and their representations with the citizen science software will be co-designed in a participatory process. This process will rely on conceptual systems mapping approaches to identify interdependencies
between social, technological and environmental changes. Associated scenario development will direct attention to towards potential future challenges and help identify socially robust leverage points for changing undesirable development trajectories. The research will investigate whether this approach can (i) engage scientists, policy makers, administrators, stakeholders and citizens in transformative social learning, (ii) enhance the repertoire for concerted action, and (iii) serve to track and evaluate resulting changes and make collective judgments on desirable development paths.

Research questions
Accordingly, in this research project we propose to investigate five overarching questions:
- What are the main challenges, drivers of change and uncertainties at the global, EU and national level that relate to the linkages between water and food security and safety, and energy provision?
- What are the main risks and vulnerabilities faced in Luxembourg with regard to the waterfood-energy nexus?
- What strategic policies and measures might help to reduce risks to water and food security and make our water food energy systems more resilient and sustainable? And what is a **desirable regional development pathway** considering possible future resource scarcities associated with development plans for the local economy?
- How can we more **effectively combine scientific inquiry with stakeholder interactions and policy-making, in a participatory process** for co-creating actionable, future-oriented and systems knowledge of the nexus?
- What potential has a citizen science tool offering a virtual space for co-creation of knowledge and representations of changes in technology, social practice and environment?

Methodology: The project serves to develop methods, including conceptual and computer-based tools to structure social learning processes for transformative change for sustainability, with a focus on water governance. The methods to be further developed in the projects include:

(1) **Collaborative conceptual systems mapping** with the aim of developing simple low order conceptual systems models as basis for a shared understanding amongst diverse stakeholder groups, assisted with computer-based tools to generate shared representations of systems dynamics, including interdependencies between social, technology and environmental subsystems, feedback loops, reasons for 'lock-ins' in unsustainable social practices, and leverage points for policy-making and changes in social practice.
(2) **Scenario approaches** for developing a shared understanding of drivers of change and uncertainties, diverse sets of values associated with alternative futures and associated development paths, improved judgment of acceptability and feasibility of diverse policy and action options through diverse perspectives.
(3) **Co-creation of a citizen science tool** for participatory monitoring and representing system dynamics and feedbacks as basis for concerted action by stakeholders.
(4) The project will also develop new approaches to document and **evaluate transformative learning**, including based on assessing changes in communication and behaviour at the individual, organisational and systemic level that can be associated with the engagement of diverse stakeholders in these processes. The documentation and analysis of different discourses in diverse groups, areas of agreement and contradictions based on discourse analysis will play central role in better informing judgment on acceptable and feasible actions.

Scientific deliverables stated in 2016 include presentations of the project's results at four international conferences (e.g. International Conference on Sustainability Science 2018 by the International Alliance of Research Universities) and a minimum of seven publications in peer-reviewed journals, such as: Journal for Cleaner Production (IF= 3,4); Current Opinion in Environmental Sustainability (IF= 3,1), Global Environmental Change (IF= 5,4), Journal of Environmental Planning and Management (IF=1,4), Futures (IF=0,9)
-Two theses: 1 Ph.D. and one Masters Thesis

Annex IV. Extracts on circular economy, technology and water savings from Expert contribution 5.

3 Scenarios for the differentiation of the Circular Economy in Luxembourg in 2045
Paul Schosseler, +IMPAKT, 16 February 2020

Text Extract:
The NEXUS project focuses on water and land in Luxembourg and we limit our analysis, therefore, to goods and services as well as activities with a strong local impact on water and land. These include land use and water services for dwelling, key economic activities such as industrial production, ICT infrastructures and services, agriculture for food and material production (e.g. crops, vegetables but also wood) and human recreation (including tourism). From the perspective of the CE, water and land are strongly interconnected through the biological cycle, where nature provides ecosystem services such as biomass production, recovery of nutrients, cleaning of water and air. Nature provides, however, also inspiration and recreation to us humans. Water is a key chemical component, as it is at the basis of all forms of life on earth, allowing for myriads of bacteria, fungi and higher living organisms to make the soil fertile. It enables the biological cycle by serving as solute in biological systems, including the transport of nutrients through our body. For the present purpose, we define the CE as a holistic approach towards the production and exchange of goods and services, taking into account the limited availability of (most) resources on our planet and respecting the regenerative capacities of the biosphere.

It is expected that the CE could provide a greater resilience facing a shortage of raw materials in key industrial sectors, contribute to the creation of local jobs for less skilled workers and reduce environmental pollution. It is, thus, also logical that the CE has been retained as one of the guiding principles for developing the NEXUS scenarios. The implementation in the different scenarios is governed, however, by the underlying socio-political value systems.

In all three scenarios the management of stocks and flows will be organized in the future according to key principles of the CE, although the implementation plays out differently, based on prevailing societal values and diverging economic frameworks. The assumption that the CE can provide solutions to cope with key drivers for socio-economic change, namely the consequences of climate change and the resulting scarcity of the natural resources water, agricultural soil and forests, is plausible in all three scenarios. The challenges ahead for getting the CE to work are important and touch a broad range of topics:

- Intergenerational conflicts and social unrest will most probably arise as the patterns for resource and land use are shifting, especially in the second and third scenarios. Innovative regulation and taxation schemes will be important to frame these disruptive changes and the younger generations need to be prepared for creating, transposing and operating these schemes. Schools need to deliver the necessary knowledge and skills, for tackling the future in an optimistic way.
- ICT is a key driver in all scenarios, especially for the implementation of the CE, and important questions linked to the management and ownership of personal and professional data need to be solved. Digital literacy and awareness have to be promoted at all levels so that society as a whole can benefit from the technological advances.
- The implementation of CE principles asks for a holistic and multi-criteria policy and decision making, both at public (state, commune) and private (company, association) level. Participatory processes and stakeholder involvement can provide valuable answers to complex problems. Finding consensus on potential solutions is time consuming but facilitates at a later stage the implementation of the solutions. Co-creation processes and other methodological approaches are not easily adopted in a linear economy and have to be learned, trained and judiciously deployed.
- As much as the adoption of CE principles in daily life depends on the appropriate societal values, the transposition in industry and the broader economy asks for a favourable entrepreneurial spirit and mindset. Companies will be important drivers for positive change, if the socio-economic and regulatory framework allows for innovative business models. The financial sector will be a key player in providing incentives and support for these business models, at regional, national and international level. Especially for the second and third scenarios it is not clear, however, in how far the local economy can connect to international markets, especially for the provision of high-tech products and non-local resources, including food and biobased materials.

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