Implementing living labs to support local climate change adaptation and resilience strategies using a system innovation approach

Alice Guittard
Isabelle La Jeunesse
Ebun Akinsete
Maria Tziva
Ana Lorena Barrueto Munoz
Alicia Blanchi-Sic
Alexandra Spyropoulou
Phoebe Koundouri

Working Paper Series
26-05
February 2026
Department of International and European Economic Studies

Implementing living labs to support local climate change adaptation and resilience strategies using a system innovation approach

Alice Guittard[1,4] Isabelle La Jeunesse[2], Ebun Akinsete[3,4,6], Maria Tziva[3], Ana Lorena Barrueto Munoz[2], Alicia Blanchi-Sic[2], Alexandra Spyropoulou[5], Phoebe Koundouri[1,3,4,6,7]

[1] ReSEES Research Laboratory, Athens University of Economics and Business, Athens, Greece
[2]CNRS Citeres laboratory, University of Tour
[3]Sustainable Development Unit, Athena Research Centre, Athens, Greece
[4]Alliance of Excellence for Research and Innovation on Aeiphoria (AE4RIA), Athens, Greece
[5]University of Thessaly, Volos, Greece
[6]Sustainable Development Solutions Network (SDSN) Global Climate Hub, Athens, Greece
[7]Department of Earth Sciences and Peterhouse, University of Cambridge, Cambridge, UK

Keywords : Living Lab ; System Innovation Approach ; Climate Change Adaptation ; Stakeholder Engagement ; System Thinking

Abstract
Climate change impacts in Europe are accelerating, creating urgent adaptation needs across diverse local contexts. This paper presents the implementation of a Systems Innovation Approach (SIA) through living labs to co-design climate resilience strategies in nine European case studies. SIA provides a structured, participatory framework for systemic change through a stepwise approach enabling the development of tailor-made sustainability strategies by co-designing a portfolio of short, mid, and long-term innovative solutions. Living labs can successfully support open innovation ecosystems by enabling knowledge exchange, trust-building, and co-creation of tailored innovation pathways for adaptation. Results demonstrate that through the SIA, living lab can enhance stakeholder networks and capacity building, co-create knowledge and mutual understanding across a diversity of stakeholders while fostering actionable strategies. However, challenges remain regarding sustaining living labs beyond project funding, maintaining engagement, and bridging planning-to-implementation gaps. The paper concludes with recommendations for institutionalizing living labs within governance frameworks to accelerate Europe’s transition toward climate resilience.

1. Introduction

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC, 2023) details the increased consequences of a 1.5°C rise in global temperature such as rising sea levels, extreme weather events, and shrinking sea ice. These effects are projected to intensify, with marked increases in the frequency and severity of heatwaves, heavy rainfall, and droughts expected in the coming years. One of AR6's most alarming conclusions is that climate change impacts on people are more widespread and severe than previously thought, with about half of the global population contending severe water scarcity for at least one month per year, high temperatures enabling the spread of vector-bone diseases, and slowing improvements in agricultural productivity. Even in the very positive scenarios, climate change will continue to have manifold impacts because of the inertia of the climatic system. Therefore, apart from climate change mitigation efforts, the global community and climate policies are increasingly focusing on adaptation, meaning limiting the impacts of climate change and safeguarding people and nature.

According to the European Environmental Agency, Europe is the fastest warming continent in the world and faces tremendous climate risks (EEA, 2024). While climate changes impacts will be felt throughout Europe, its effects will vary significantly locally. Some regions will experience higher temperature rises, while some others will face more intense storms and rainfall, or be affected by water scarcity. In addition, inequality makes some communities more vulnerable to climate changes impacts than others. For example, areas with populations whose livelihoods are primarily natural resource-based have disproportionate exposure to changes in ecological systems (Alamanos et al., 2022). Likewise, urban areas and especially lower socioeconomic groups within these areas, are more exposed to air pollution, noise, and high temperatures (van Daalen et al., 2022). Therefore, climate change adaptation strategies must be designed and implemented in terms of local environmental and socio-economic conditions (McCann & Soete, 2020). To achieve this, different authors stress the urgency for scientifically informed place-based approaches on designing climate change adaptation polices (Adams, 2024; Tiller et al., 2023).

The aim of this paper is to contribute to the ongoing discussion about the ways in which the science-society interface can contribute to climate change adaption in Europe using a Systems Innovations Approach (SIA) implemented in living labs. SIA is a methodological framework to orchestrate systemic and holistic change when facing complex problem such as climate change (Alamanos et al., 2022; De Vicente Lopez & Matti, 2016; Koundouri, et al., 2022). SIA has been effectively applied at the regional and local levels (Alamanos et al., 2022; Guittard et al., 2024). It comprises a stepwise participatory process, taking place in living labs, in which a sustainability challenge and the underlying complex systems are demarcated and analysed, desired futures are defined and innovative solutions and levers for change are identified.

SIA involves the long-term scientifically guided engagement of a broad set of stakeholders in living blabs. First, working with grand sustainability challenges, such as climate change, requires considering biophysical, technological and social elements, and identifying holistic solutions. This can only be achieved by involving multi-actor groups with diverse knowledge and capabilities (Folke et al., 2010; Koundouri et al., 2024). Second, engagement of a broad set of stakeholders in research has been identified as a valuable governance tool, particularly at the regional level (Guittard et al., 2024; Wittmayer et al., 2014). Lack of awareness, high uncertainty, diverse perspectives, and conflicts are often innate in sustainability related challenges (Alamanos, 2022). The engagement of a broad set of stakeholders allows to address a broader societal agenda, negotiating over alternative pathways, and reflexivity.

Moreover, such a multi-actor approach has been beneficial in delivering placed-based policy recommendations that are widely acceptable, and the translation of research results into existing policy frameworks (Adams et al., 2024).

Effective and efficient long-term engagement of stakeholders to address place-based sustainability challenges requires the creation of new arena of knowledge exchange that enables the co-identification of tailor-made solutions within a specific context while fostering trust and the development of new relationships. Living labs are more and more recognized as a tool to support and sustain long-term stakeholder engagement. Living labs, as defined by European Network of Living Labs, are "*open innovation ecosystems in real-life environments based on a systematic user co-creation approach that integrates research and innovation activities in communities and/or multi-stakeholder environments, placing citizens and/or end-users at the centre of the innovation process*" are particularly well suited to anchor this process in real word systems (ENoLL, 2024). Early living labs mainly involved users in technological innovation processes to design and test new products and services i.e. (Eriksson et al., 2006). In recent years, the value of living labs as a sustainability-oriented approach has gained attention (Adams et al., 2024; Compagnucci et al., 2021; Luederitz et al., 2017). Living labs can engage a diverse set of stakeholders to co-create knowledge related to a context-specific sustainability challenges, and allow for the co-development of holistic solutions. Because the participation in a living lab aims at sustaining a long-term involvement, stakeholders can be engaged in an iterative process in which learning and experimenting is continuous. Indeed, literature argues that living labs are a practical tool for improving sustainability by facilitating both collaborative long-term learning within a diverse set of actors, as well as experimentation with solutions that are directly relevant to stakeholders (Schäpke et al., 2018; Bulkeley et al., 2016; Compagnucci et al., 2021; Hölscher et al., 2024).

Nevertheless, although the engagement of stakeholders in living labs are a popular phenomenon in the science policy interface, there is an array of methodologies, structures, and practices that are being performed. It is therefore crucial to analyse consistent approaches across several case studies in different local geographical context to develop an understanding on how systemic innovation, in the case of climate change adaptation, can be fostered.

In this paper, we present how living labs were used, following a SIA, to engage stakeholders in an iterative and participatory process aiming at better understanding and addressing local climate change challenges, as well as provide lessons learned from the implementation of living labs in nine different European case studies.

2. Innovation for climate resilient European communities

As mentioned already, the impacts of climate change are accelerating and increasingly pressing with dramatic financial and societal cost. From flash flood in Germany and Spain to extreme fires in Portugal and Greece, it becomes extremely urgent for European regions to adapt to new climatic conditions. Adaptation options involve innovation in the structural/physical, social, and institutional spheres (IPCC, 2023). Innovation can range from the diffusion of new technologies to changes in governance structures and risk management policies to develop adaptive capacity through i.e. the establishment of novel institutional structures for knowledge diffusion (Falk et al., 2021; Ferreira et al., 2020; Domanski, et al, 2020; Durán-Romero et al., 2020). The adaptation options that will be selected across geographical areas vary tremendously because the type and severity of the impacts of climate change will also vary from place to place, depending on physical vulnerability, the degree of socio-economic development, natural and human adaptive capacity (McCann & Soete, 2020). Therefore, a portfolio of tailor-made solutions will need to be implemented capable of addressing local needs and challenges which cannot be properly understood without a stakeholder engagement approach including tools capable of harnessing the necessary knowledge. Moreover, to effectively address climate change impacts locally will need to be implemented across several sectors and their interlinked impact should result in systemic change.

SIA aims to contribute to the development of such systemic change processes through the **long-term engagement of stakeholders in living labs**. Conceptually, SIA has been based on systems thinking and the transitions management approach (Rotmans et al., 2001; Loorbach, 2010; Meadows, 2008). The idea of a transition emerged to conceptualize processes of systemic change as a response to complex environmental problems (Köhler et al., 2019). A societal transition is understood as a shift from a dominant system, characterized by a specific socio-technical regime, to another (Geels and Schot, 2007*),* through innovations encompassing changes in technologies, as well as in corresponding social structures, such as culture, norms, markets, policies and user practices (Markard et al., 2012). A considerable number of studies analyse historical examples of transitions and employ the concept of an "innovation pathway", to analyse unfolding socio-technical innovation processes that lead to systemic change (i.e. Kern & Markard, 2016; Kungl & Geels, 2018; Normann, 2017). The transitions management perspective has particularly focused on governing transitions. It pertains that actor activities can be deliberately influenced in such a way that they lead to accelerated systemic change (Köhler et al., 2019). It is mainly aimed at policy makers who are willing to enable change for sustainability in the European science-policy interface. The approach uses living labs to organize multi-actor participatory activities required to collaboratively shift to new ways of doing to achieve local climate change adaptation.

3. Materials and methods

3.1 Systems Innovation Approach in living labs

SIA comprises a stepwise process to engage stakeholders in living labs with the end goal of co-designing "innovation pathways", as roadmaps for a system change to address complex sustainability challenge. A system can be described as an interconnected set of elements that is coherently organized in such a way that it produces its own pattern of behaviour (Meadows, 2008). For SIA, a system is delineated according to a sustainability challenge to be addressed in a particular geographic location. System elements are comprised by actors, institutions, practices, policies, and innovations relevant to a sustainability challenge in a geographical or administrative area (e.g. a municipality, a region, an island, a port, a sea basin). The holistic understanding of the system and its behaviour will allow the further exploration of systemic change, as well as serve as a tool for consensus building among stakeholders in the participatory processes implemented in living labs (Papadaki et al., 2023). Today, various living lab concepts coexist, depending on their methodological approach and background theory, format, and purpose (McCrory et al., 2020). Within this research living labs are understood as sustainability-oriented living labs or labs for sustainability transition experiments (Luederitz et al., 2017), a cross-organizational collaborative initiative between actors from academia and society (government, industry and civil society) where they physically meet at regular interval (in participatory workshop, focus groups, world café, site visit, public events) and virtually interact (online meeting and survey, virtual event, etc.). They are used to foster mutual learning and knowledge exchange across various sectors and stakeholder groups impacted by a specific sustainability change, in this case climate change, agreed on long-term sustainability goals, identify innovative solutions and co-design pathways to transition from the present toa future desired state.

3.1.1. **Scope and stakeholder mapping**

The SIA approach starts with the **definition of the scope of the living lab** by clearly defining the systems boundaries (spatial, temporal or conceptual) and the set focus and objectives ('what is the aim of the living lab and the expected outcome(s)?'). A crucial part is identifying the set of stakeholders who will be invited to join the living lab participatory processes. The identification of stakeholders is conducted through a structured method informed by a stakeholder mapping (André et al., 2012). First, relevant categories of stakeholders from the quadruple helix (academia; industry; government; civil society) can be identified according to their capacity to influence the system behaviour but also their knowledge regarding how the system behave, for instance, entrepreneurs, citizens, policy makers operating in various sectors impacting and impacted by the sustainability challenge the living lab aims to address. Afterwards, specific stakeholders (organizations and/or individuals) for the identified categories are inventoried into a "long list of stakeholders". To narrow down the initial long list of stakeholders an "influence/interest matrix" analysis is conducted (Newcombe R. 2003; Wal Chiwala et al. 2025). 'Influence' refers to the degree of power and capacity the stakeholder has to generate change. 'Interest' refers to the likelihood that the stakeholder will participate in the living lab.

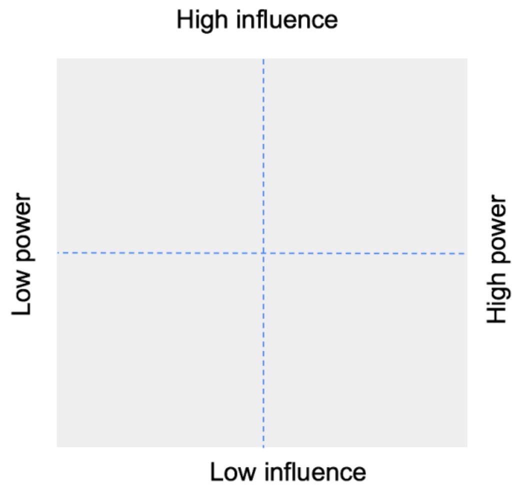

Figure 1: Stakeholder mapping - *Power/influence matrix*

The stakeholders within the upper right quadrant (high influence/high interest) constitute the core group of stakeholders to be engage in the living lab and will serve as the basis for recruiting living labs participants. In addition, consideration is also given to the inclusion of stakeholders at the upper limits of the top left and the bottom right quadrants. The analysis of stakeholders based on this matrix allows for the identification of stakeholders to whom the work is most relevant and who are most likely to be engaged in the research process. While it is advantageous to utilize the living labs as an opportunity to engage influential decision-makers, the examination of 'Interest' also allows for the identification of those stakeholders who will invest time and effort into supporting the research process, while being able to freely and actively participate. Finally, to validate the choice of key stakeholders, the results of the analysis are evaluated by independent experts, and necessary revisions are implemented accordingly.

Following the identification of stakeholders, the is implemented by convening the selected group of stakeholders representing various sector and groups from the quadruple helix (public and private sector, academia and civil society) that will form the core of the living lab. They will interact on a regular basis using participatory workshops, focus groups, online meetings, study visit, and other means of communication (newsletter, survey, etc.).
The living lab implementation process follows the SIA comprises four distinctive phases: 1. system mapping 2. visioning 3. innovation pathways 4. system leverage points. These four stages are co-developed with stakeholders in living labs over a period which allows learning and experimentation.

3.1.2 **System mapping**

Sustainability challenges are societal problems that are highly complex. Divergent clams, normative values, problem framings, and interests, are inherent in such challenges. In addition, complexity in terms of multi-dimensional nature of problems and uncertainty due to lack of knowledge also add the struggle in clearly defining such problems and reaching consensus on the solution side. The first step of the SIA aims at ensuring that all stakeholders engaged in the living lab share a common understanding of the sustainability challenge to tackled, how it impacts the system the living lab is focusing on and how they affect (positively or negatively) this system. The participatory processes start with the implementation of a multi-stakeholder workshop focusing on an open discussion aiming at graphically representing the stakeholder's mental perceptions of their system through the identification of the main issues, opportunities, obstacles, and solutions in the context of the sustainability challenge in the region. Emphasis is given on the interconnections between the physical and social elements of the systems, which include actors, institutions and innovations, to understand systems behaviour over time. Results of this analysis are depicted in a mental map, which allows the representation of the interconnected systems and illustrates the multiple relationships between systems elements and systems behaviour. Through this cognitive exercise, different representations of the system based on stakeholder background, experiences, knowledge, and perceptions of the environment, are heard, discussed and integrated to build a comprehensive graphical representation of the system that the living lab will focus on. The result is reaching consensus on the different elements of the system and key interactions across sectors and ecosystems, as well as a common understanding of main challenges.

3.1.3 **Envisioning**

The next step is about envisioning a sustainable future. Visioning is a foresight method that attempts to create a feasible and desirable future scenario in which current problems are solved. To achieve this in a living lab context, stakeholders are asked to develop a common vision describing a desirable sustainable future in which the key sustainability challenge, the problem statement, has been resolved. The development of the vision can be prompted by attempting to answer an open question i.e. "how would you like the region to look like in 2050?". Following this open discussion, stakeholders further analyse their visions by participating in visioning exercises (De Vicente Lopez & Matti, 2016). The purpose here is to build a shared positive vision of the future across sectors and stakeholder groups (academia, business, policy makers, civil society). Stakeholders are encouraged to consider long-term systemic transitions, and not to be confined by the status quo or the way things are at present. Visioning is not a predictive exercise but rather a mean to provide a sense of direction, a goal to be achieved by the innovation pathways. To guide visioning exercises, helpful material can be provided to the stakeholders. For example, guiding principles can be extracted from the Sustainable Development Goals targets which are relevant to regions and the sustainability challenges can be bought up.

3.1.4 **Co-design of pathways**

The co-development of innovation pathways is based on participatory back-casting. In a participatory back-casting exercise, stakeholders analyse how the desirable future previously envisaged can be achieved by looking back from this future and identifying steps to get there. It has shown great value in exploring and evaluating possible system innovations towards sustainability (Quist, 2007; Kishita et al., 2024). This is because participatory back casting, unlike other scenario approaches which focus on possible scenarios, has an explicit normative component which allows imagining normative goals and the "out of the box" pathways that are not necessarily parts of dominant trends. Practically, stakeholders are encouraged to identify changes and key milestones for the long, mid and short term which will contribute to the development of innovation pathways. At this point the term innovation is not limited to technological innovations but also includes social ones, such as new political or economic frameworks, significant changes in actor configuration, and changes in cultural conventions.

In this step there are three important constituents to achieve designing innovation pathways. First, necessary changes and milestones for the future need to be plotted along a realistic timeline which depicts their temporal relationship. Second, the actors that can influence those changes need to be identified. Third, these results should be coupled with potentially enabling innovations. To facilitate this exercise, conceptual models can be helpful, for example De Vicente Lopez & Matti (2016) propose the "futures radar". The outcome of the participatory back casting exercise will be coherent innovation pathways which include a temporal sequence off changes and the actors that can enable those changes.

3..1.5 **System leverage points**

The final aims to produce policy relevant knowledge, by analysing barriers that could obstruct and/or hinder the implementation of the innovation pathways, as well as enabling conditions that would support it. To achieve a comprehensive analysis, heuristics that analyse types of different barriers can be employed. For example, the PESTLE framework[1] initially developed to analyse the external factors that can influence an organization by looking at the Political, Economic, Social, Technological, Legal, and Environmental factors can be used to map barriers and enablers for implementing innovation pathways.

3.2 Application to climate resilience and adaptation European regions

3.2.1 **A diversified geographical context**

The ARSINOE project brought together nine case studies in different European communities to develop a framework for multi-stakeholder engagement in living labs aiming to address climate change impacts and implement innovative adaptation solutions. The nine case studies were selected according to two criteria. First, each case study should revolve around a climate change adaptation challenge in the local scale. Second, the selection should comprise cases

[1] https://pestleanalysis.com/what-is-pestle-analysis/

that vary in the type of climate change adaptation challenge, the degree of socio-economic development of the area, and natural and human adaptive capacity, to contribute to the generalizability of the results and the robustness of the framework. The characteristics of the nine cases selected for the ASINOE project are summarized in the table 1 below.

Table 1: Description of ARSINOE case studies

Case studies	Location	Geography	Main Climate change adaptation challenge
1	Athens, Greece	City	Extreme heat
2	Mediterranean ports (Piraeus, Greece Limassol, Cyprus Valencia, Spain)	Ports	Extreme weather damage on port and coastal infrastructure
3	Main river basin	River basin	Summer droughts, heat waves and winter floods
4	Ohrid and the Prespa Lakes, south-western Europe	Lakes	Water scarcity
5	Canary Islands, Spain	Islands	Vulnerability of aquifers in volcanic islands water scarcity
6	Black sea (Roumania; Bulgaria; Turkiye)	Delta and Sea basin	Water scarcity, flooding, and pressure on marine and freshwater ecosystems
7	Southern Denmark	Coastal areas	Flooding and storm surge
8	Torbay, Southwest England	Inland riverine area	Flooding
9	Sardinia, Italy	Island	Water scarcity

In the ARSINOE project, every case study focused on co-designing innovation pathways for climate change adaptation with local stakeholders. The SIA was operationalized through the implementation of a living lab in each case study over a period of 40 months (table 2). Apart from the participatory processes involving stakeholders, researchers involved in the project were committed in an iterative approach. Therefore, it was important to reflect on results and revise if necessary. For example, the mental map of the system was evaluated in terms of clarity, hierarchy and focus. The main challenges discussed during living lab workshops had to be reflected as per the key elements of the system, such as a specific sector, should have appeared as dominant. Moreover, a critical evaluation of the participants in living lab sessions was necessary. In case key stakeholders were missing, it was important to arrange bilateral meetings to include those missing perspectives and potential knowledge gaps were rectified by inviting the relevant actors to participate in next steps.

Table 2: ARSINOE living lab's details

Case studies	Location	Living Lab focus	Number of stakeholders engaged in a living lab	Sector represented
1	Athens, Greece	Mitigating urban heat through nature-based solutions	30	Water, Energy, Transportation, Health, Urban planning, Biodiversity, Tourism, Construction
2	Mediterranean ports (Piraeus, Greece Limassol, Cyprus Valencia, Spain)	Critical climate change impacts on port operations and infrastructures	12-30 per port	Shipping, Energy, Transportation, Port operations & Infrastructure, Insurance,
3	Main river basin (Germany)	Integrated water resource management and climate change resilience	12	Water, Energy, Environment, Agriculture, Fishing, Shipping, Mobility, Waste Management
4	Ohrid and the Prespa Lakes, south-western Europe (Albania – Macedonia – Greece)	Improve climate resilience in environmental, economic, and social sectors related to water use	38 (national working group and transboundary living lab)	Social sector, Water management, Health, Environmental systems and biodiversity, Agriculture, Fishery, Forestry, Hydropower generation, Tourism, Cultural heritage
5	Canary Islands, Spain (Tenerife)	Impact of temperature raise on the Water-Food nexus	14	Agriculture, Water, Tourism, Wastewater
6	Black sea (Romania; Bulgaria; Türkiye)	Water resource management from source to sea in the Western Black Sea region in the	49 (3 national working groups and one international living lab)	Water, Infrastructure, Aquaculture/Agriculture, Environment, Tourism, Energy; Health; Waste management; Urban development

		context of climate change		
7	Southern Denmark	Security from flooding in the area along Esbjerg city and harbor.	14	Business and industry, Harbor, Investment (business and urban development), Housing.
8	Torbay, Southwest England	Interconnections amongst water, health, community & infrastructure and ensuring resilience of all these	17	Water, Community, Health, Energy/power, Transport, Climate planning
9	Sardinia, Italy	Improving durum wheat sustainable food production and adaptation to climate change	21	Agricultural sector, Food and agri-food, Handicraft, Water, Policy, Social sector.

3.2.2. **Operationalisation of the SIA**

Table 3 summarizes the living lab activities, method and tools used, and the corresponding SIA steps.

Table 3: Operationalization of SIA in ARSINOE project case studies.

SIA steps	Scope	Method and tools	Main outcome
Step 1 - Problem scoping	Co-development of mental map and system boundaries (special/temporal/conceptual)	- Living lab participatory workshop - System thinking approach - Causal Loop Diagram (CLD)	- A mental map representing stakeholders' diverse perceptions of the system - A problem statement
	Fine tune and simplify the CLD	Desktop work One-and-one meeting with key stakeholders	
	- Review and validation of system map	Living Lab participatory workshop including individual and group envisioning activities.	

	- Validate the problem statement - Co-development of a future vision	Use of visuals to trigger imagination based on the concept of seeds for Anthropocene[2]	
	- A future narrative describing how the case study successfully adapted to climate change agreed upon across sector and stakeholder	- Research team merges the groups' vision - Stakeholders validate the merged vision through online interactions	
Step 3 – Co-design of Innovation pathways	Identification of key sectors in needs of innovation for climate change adaptation	Vision analysis	Key sector which will be the focus of the innovation pathways
	Strengthen stakeholder engagement in the living lab	Case study visit	Ensure living lab activities and outputs are anchored within local context
	Identification of potential innovations necessary to achieve the vision	- Online interactions with stakeholders to develop an inventory of key innovations adapted to the case study climate change challenge - Desktop research - Climate Innovation Window[3]	short-, mid- and long-term milestones and supporting innovations
	Co-design of innovation pathways working backwords from the desired future	- Living Lab participatory workshop - Back-casting approach	Innovation pathways outline
Step 4 - System leverage points	Consolidate the Innovation pathways and identification of supporting actions	- One and one meeting with key stakeholders and experts - Desktop research - Policy analysis	A coherent set of short-, mid- and long-term milestones and innovations
	Identification of barriers and enablers	- PESTLE framework	A set of political, economic, social, technological, legal,

[2] https://goodanthropocenes.net/
[3] https://climateinnovationwindow.eu/

	for implementing the innovation pathways	- One and one meeting with key stakeholders and experts - Desktop research	and environmental barriers and enablers

During the first round of workshops, stakeholders were engaged in an open discussion, aimed at identifying the main issues, opportunities, obstacles and solutions in the context of climate change impacts (present and future) in their region by co-creating a mental map. The mental mapping (Causal Loop Diagram) refers to the graphical representation of the issues brought forward by the workshop participants, linking the elements mentioned. Causality between key variables is an important aspect of the mental maps (sometimes referred to as 'mind maps'). Through this cognitive exercise, different representations of the system based on stakeholder background, experiences, knowledge, and perceptions of the environment, were heard, discussed and integrated to build a comprehensive graphical representation (a map) of the system the living lab focuses on. The result is a common understanding of the different elements of the system and key interactions across sectors and ecosystems where main issues and challenges are highlighted.

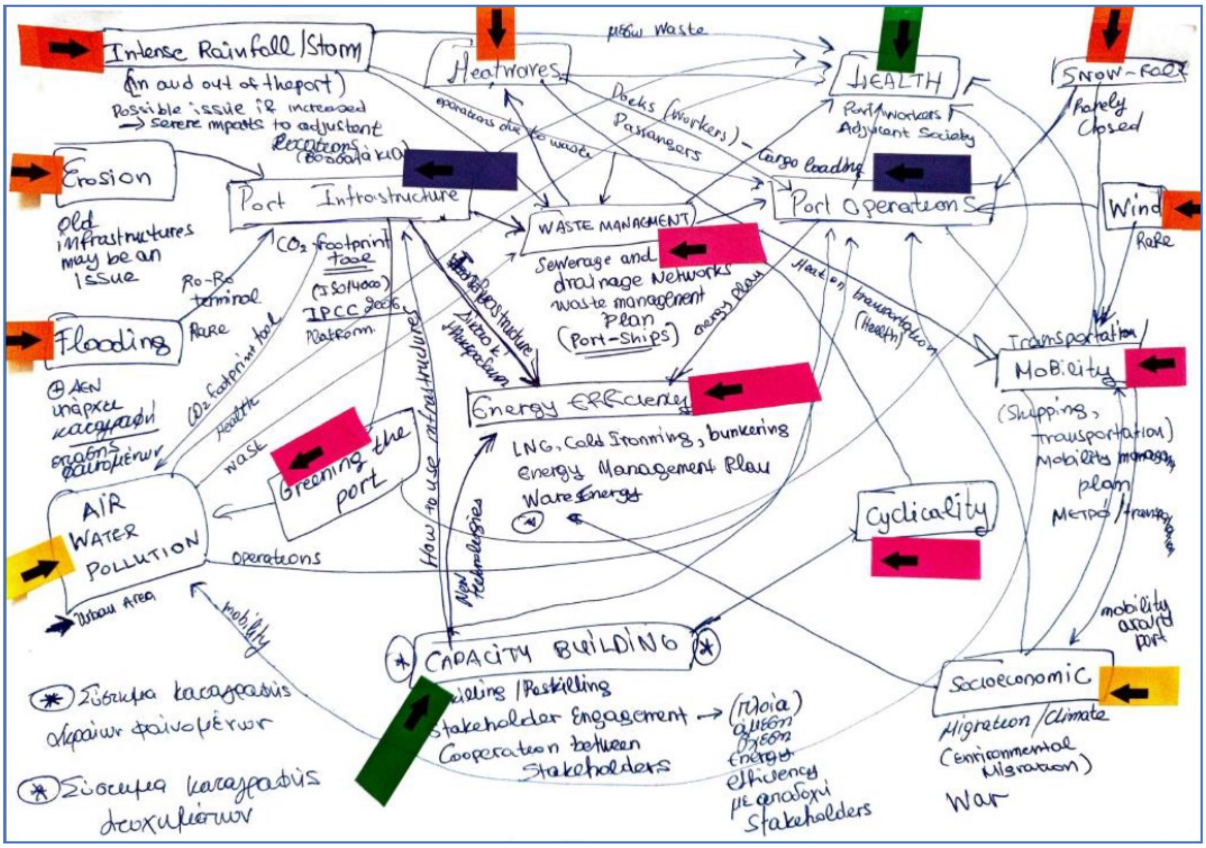

Figure 2: Example of a mental map co-developed with stakeholders during the first round of ARSINOE living lab workshops

While the first step focuses on the climate change challenges and local consequences described in the mental map (e.g. figure 2), the second step aims at moving away from a problem driven discussion by first reviewing the mental map, to ensure everybody has a

common understanding of the system and critical climate change issues to be solved. The second round of living lab workshops seek to federate all stakeholders around a set of long-term adaptation goals, looking at a positive, sustainable future, leaving no one behind. Those goals are extracted from the 2050 voluntary ambitious vision describing how each case study (e.g. the city, the port, the island) have successfully adapted to climate change impacts (e.g. extreme heat, flooding; drought; etc.) on various sectors (e.g. tourism; agriculture; water management; urban development; etc.) and communities (e.g. fishermen; farmers; urban citizens; elderly; islanders; etc.).
During the third step the living lab is focusing on solutions to adapt to climate change by co-identifying a portfolio of innovations across sectors necessary to achieve the case study vision. Addressing climate change requires a combination of technological and social innovations. Technological innovations involve the development of new tools, processes, and systems for both mitigation and adaptation, whereas social innovations concentrate on modifying behaviors, policies, and societal norms to promote sustainability. The ARSINOE innovation pathways for climate adaptation focus on key areas of intervention, including water management, community engagement and education, environment and biodiversity, soil management and agriculture, energy, climate change risk management, fishery, tourism, governance and planning, and urban greening. Utilizing the PESTLE framework, case study leaders have collaboratively identified with local stakeholders' key enablers and barriers within their regions, as system leverage points, to effectively implementing the portfolio of innovations co-created with local stakeholders (step four). Significant barriers to implementing climate adaptation-related innovations include knowledge gaps, data issues and deficiencies, cultural resistance to change, low awareness of climate change and its impacts, insufficient funding, private sector reluctance to invest in climate technologies, high upfront costs, inadequate climate policies, policy inconsistencies, political instability, legal delays, and data privacy concerns. However, a favorable environment for adopting these climate innovations is gradually emerging, supported by EU policies and funding, the establishment of cooperation mechanisms between research and industry, economic incentives for adopting green practices, increased pressure from civil society on policymakers, long-term savings from reduced damage costs, the development of education and awareness campaigns, growing environmental activism and community networks, and the proliferation of local innovation hubs for climate adaptation.

To ensure methodological consistency and comparability of results across the nine ARSINOE living labs, a dedicated coordination research team provided continuous support through structured methodological guidelines, targeted training, and a standardized reporting protocol. Prior to each participatory workshop, the coordination team organized preparatory training sessions (conducted either in person or online) for the nine local facilitation teams. These sessions included a mock workshop designed to enable an in-depth understanding of the planned activities and tools. Furthermore, individualized pre-workshop consultations

were held to review planning, while post-workshop debriefings facilitated critical reflection on implementation outcomes, identifying effective practices and areas for improvement.
In addition, weekly online meetings were convened among the nine living lab leaders to present progress updates, exchange feedback, and share lessons learned. This iterative process allowed early implementers to provide practical insights and recommendations to subsequent teams, fostering collective learning and adaptive management.
For each workshop, the coordination team proposed a general agenda while allowing flexibility for local adaptation, including the integration of context-specific activities and interactive sessions. A standardized reporting template was also introduced to ensure consistency in documentation, enable cross-lab comparison, and support methodological reflection aimed at enhancing replicability.

5. Discussion: ARSINOE living labs impacts

5.1 A flexible, iterative, and adaptive methodology

The Systems Innovation Approach implemented in the ARSINOE living labs provided a robust framework for engaging stakeholders in a collaborative, problem-solving process. This approach enabled the co-creation of actionable strategies in the form of tailored roadmaps of innovations and supporting measures adapted to specific contexts. It is particularly effective for addressing complex, multifaceted sustainability challenges (such as climate change adaptation) that demand holistic, systemic solutions and multi-stakeholder engagement.
SIA is highly adaptable, allowing customization to the needs and challenges within defined system boundaries of varying scales (e.g., a port, city, island, or region) and scopes (e.g., urban planning, agriculture, ecosystems, or risk management). The ARSINOE project demonstrated this flexibility across diverse contexts with consistent success. Furthermore, the use of living labs created an environment where SIA could integrate complementary sustainability approaches, tools, and activities, provided they aligned with the overarching goal: offering a safe space for knowledge exchange and the co-design of long-term innovative solutions.
The application of living labs across all ARSINOE case studies confirmed the effectiveness of SIA as a participatory framework. Structured around three core workshops, the living labs facilitated a coherent, iterative process that actively engaged stakeholders and promoted systems thinking in diverse regional settings. Between workshops, stakeholders remained involved through progress updates, co-development of inputs, and validation of outputs, ensuring continuity and shared ownership throughout the process.

5.2. Networking and capacity building

To measure the immediate impact of the ARSINOE living labs, a survey was conducted targeting living lab participants over a 40 months period of time. With a response rate of 52%, the survey conducted across the 9 case studies, in local language, collected 119 responses.

Overall, the ARSINOE living labs were rated with a high level of satisfaction among participants. Most stakeholders expressed a high degree of satisfaction in participating in the living lab workshops, highlighting the living lab role in building competencies, enhancing knowledge, and generating concrete benefits for participants, while very few reported negative experiences. More specifically, the immediate impacts of the living lab process can be expressed in terms of **i**) Create new contacts and network, **ii**) improving knowledge in climate change, resilience and adaptation, **iii**) Help linking local policy to action, **iv**) feeling of being involve in concrete actions, **v**) increase awareness of the Sustainable Development Goals, **vi**) Develop new skills.

The ARSINOE living labs were praised first and foremost for the opportunity they offered in **bringing together representatives across sectors** at the same table, in a context where local governance arrangements still work in silos. The living lab participatory process triggered change in the participants network and dialogue, by allowing them to speak louder about the sustainability priority challenges at local level, and also through the expansion of stakeholder networks at the collective level and contributing to enlarge the individual networks of each participant. Participants reported increased exposure to new collaborations, ideas, and cross-sectoral interactions, demonstrating the added value of the ARSINOE approach in fostering both systemic and personal-level connectivity across the climate innovation ecosystem. Additionally, through the co-design process of innovation pathways, the living lab processes increased the social acceptance of innovative approaches and solutions.

The second most noticeable impact of ARSINOE living labs can be expressed in terms of **capacity building** regarding climate related issues by improving knowledge and understanding in terms of local knowledge in climate change, resilience, and adaptation (e.g. climate change risks and consequences), increasing awareness of the Sustainable Development Goals (SDGs) and environmental issues (e.g. present and future climate change vulnerability and impacts). To a lesser extent, participants reported having developed new skills (e.g. in terms of system thinking) and feeling more equipped to communicate across sector.

5.3 **Remaining challenges**

ARSINOE living labs, through the SIA approach and their challenge-driven focus, are explicitly oriented toward sustainability (McCrory et al., 2020). They provide a space where stakeholders meet regularly to co-create knowledge and co-design roadmaps for change toward a sustainable future. However, these labs operated with dedicated funding and human resources only for a limited period. Despite high participant satisfaction and recognition of the positive impacts of multi-stakeholder engagement, particularly in advancing local climate policy adaptation, the long-term sustainability of the living labs beyond the project remains uncertain. To date, only one lab has secured follow-up funding through a new EU project. While local policymakers (e.g., municipalities, regions) acknowledge the benefits for governance, they often lack the time and financial capacity to maintain such initiatives. Ultimately, the survival of a living lab beyond the project cycle largely depends on the commitment of local research teams to sustain stakeholder engagement. Embedding long-term sustainability as a core objective from the start could significantly improve the chances of these labs continuing beyond the project lifetime.

A second challenge for sustainability-oriented living labs, such as those in ARSINOE, is maintaining stakeholder engagement over time. Instability, competing priorities, and resource constraints often limit participation. Increased mobility of personnel across organizations and sectors further complicates continuity. This calls for research into strategies that sustain motivation, such as tailored communication plans, continuous feedback loops, and the involvement of local "anchor stakeholders" who can provide stability.

Stakeholder feedback across case studies highlights both the difficulties and opportunities inherent in multi-stakeholder processes addressing complex challenges like climate change. A recurring observation is the persistence of deeply rooted differences in perspectives and interests, often coupled with reluctance to move beyond entrenched positions. As one participant noted: *"As expected, there are very different points of view and, unfortunately, in some cases, no apparent willingness to make adjustments or changes. It would be desirable for all parties involved to recognize that a black-and-white view does not benefit anyone and that solutions can only be found by leaving familiar and comfortable zones."* This underscores the need to cultivate a culture of openness, encouraging stakeholders to step outside traditional silos and explore common ground. While polarization, internal conflict, and short-term thinking remain significant barriers, they also highlight the importance of ongoing, well-designed engagement that prioritizes inclusivity, critical reflection, and shared long-term goals. Addressing these issues head-on can enhance future initiatives and build the collective capacity needed for sustainable transformation across European regions.

Finally, another key challenge lies in translating locally generated knowledge into actionable, cross-scale planning and implementation. While living lab activities and outputs were perceived as meaningful, some participants expressed uncertainty about how to operationalize innovation pathways. As one stakeholder observed: *"It will be nice if such initiatives can continue with more implementation actions. It is not clear how to implement the technologies discussed in our areas."* This feedback emphasizes the need to bridge the gap between planning and execution within the SIA approach.

Conclusion

The ARSINOE living labs, through the Systems Innovation Approach (SIA), offered a dynamic stakeholder engagement framework for addressing complex sustainability challenges such as climate change adaptation. By enabling cross-sectoral knowledge sharing and mutual understanding, the development of a systems thinking mindset, and the co-design of innovation pathways, SIA enables the development of tailored, actionable strategies that reflect local contexts and priorities. The iterative and participatory nature of living labs proved effective in building trust, enhancing knowledge, and strengthening networks across sectors, thereby contributing to more inclusive and resilient governance structures.

However, the ARSINOE living labs also revealed critical challenges that must be addressed to ensure long-term impact. These include the sustainability of living labs themselves beyond project funding, the difficulty of maintaining stakeholder engagement over time, and the gap between planning and implementation of innovation pathways. Overcoming these barriers will require embedding long-term sustainability objectives from the very beginning of the process, designing strategies to sustain motivation and participation, and creating mechanisms to translate locally generated knowledge into solution Implemented within the life cycle of the sustainability oriented living lab.

Future research and policy efforts should focus on institutionalizing living lab methodologies within regional governance frameworks, securing stable funding streams, and strengthening capacity for implementation. By doing so, living labs can evolve from project-based experiments into enduring platforms for systemic innovation—accelerating Europe’s transition toward climate resilience and sustainability.

Author Contributions

Conceptualization, Alice Guittard, Isabelle La Jeunesse and Ebun Akinsete; Data curation, Alice Guittard, Isabelle La Jeunesse, Ebun Akinsete, Ana Munoz and Alicia Blanchi-Sic; Formal analysis, Alice Guittard, Isabelle La Jeunesse and Ana Munoz; Funding acquisition, Phoebe Koundouri; Investigation, Alexandra Spyropoulou; Methodology, Alice Guittard and Ebun Akinsete; Supervision, Isabelle La Jeunesse, Ebun Akinsete and Phoebe Koundouri; Validation, Isabelle La Jeunesse; Writing – original draft, Alice Guittard and Maria Tziva; Writing – review & editing, Isabelle La Jeunesse, Ebun Akinsete and Alexandra Spyropoulou.

Acknowledgments

ARSINOE has received funding from the European Union’s Horizon H2020 innovation action programme under grant agreement 101037424.

References

Alamanos, A., Koundouri, P., Papadaki, L., Pliakou, T., & Toli, E. (2022). Water for tomorrow: A living lab on the creation of the science-policy-stakeholder interface. Water, 14(18), 2879.

Alamanos, A., Rolston, A., & Papaioannou, G. (2021). Development of a decision support system for sustainable environmental management and stakeholder engagement. Hydrology, 8(1), 40.

André, K., Simonsson, L., Swartling, Å. G., & Linnér, B. O. (2012). Method development for identifying and analysing stakeholders in climate change adaptation processes. Journal of Environmental Policy & Planning, 14(3), 243-261.

Adams, C., Moglia, M., & Frantzeskaki, N. (2024). Design principles for mainstreaming of nature-based solutions in cities: A proposal for future pathways. Nature-Based Solutions, 6, 100155.

Bosch, O. J. H., C. A. King, J. L. Herbohn, I. W. Russell, C. S. Smith. 2007. Getting the big picture in natural resource management – systems thinking as "method" for scientists, policy makers and other stakeholders. System Research 24: 217 – 232. https://doi.org/10.1002/sres.818.

Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., ... & Palgan, Y. V. (2016). Urban living labs: governing urban sustainability transitions. Current opinion in environmental sustainability, 22, 13-17.

Chiwala B, Makasa M, Zulu JM (2025) Power and interest levels in safely managed sanitation services in Zambia: A stakeholder mapping. PLoS One 20(11): e0335130. https://doi.org/10.1371/journal.pone.0335130

Compagnucci, L., Spigarelli, F., Coelho, J., & Duarte, C. (2021). Living Labs and user engagement for innovation and sustainability. Journal of Cleaner Production, 289, 125721.

de Geus, T., Wittmayer, J. M., & Vogelzang, F. (2022). Biting the bullet: Addressing the democratic legitimacy of transition management. Environmental Innovation and Societal Transitions, 42, 201-218

Domanski, D., Howaldt, J., & Kaletka, C. (2020). A comprehensive concept of social innovation and its implications for the local context–on the growing importance of social innovation ecosystems and infrastructures. European planning studies, 28(3), 454-474.

Durán-Romero, G., López, A. M., Beliaeva, T., Ferasso, M., Garonne, C., & Jones, P. (2020). Bridging the gap between circular economy and climate change mitigation policies through eco-innovations and Quintuple Helix Model. Technological Forecasting and Social Change, 160, 120246.

EEA, 2024: European Climate Risk Assessment (EUCRA). European Environmental Agency. doi:10.2800/204249

ENoLL. (2024). Living Labs - ENoLL. https://enoll.org/living-labs/#living-labs

Eriksson, M., Niitamo, V. P., Kulkki, S., & Hribernik, K. A. (2006, June). Living labs as a multi-contextual R&D methodology. In 2006 IEEE International Technology Management Conference (ICE) (pp. 1-8). IEEE.

European Commission (2018) Mission-Oriented Research & Innovation in the European Union: A Problem-solving Approach to Fuel Innovation-led Growth. Directorate-General for Research and Innovation. Brussels: European Commission.
Folke, C., S. R. Carpenter, B. Walker, M. Scheffer, T. Chapin, and J. Rockström. (2010). Resilience thinking: integrating resilience, adaptability and transformability. Ecology and Society 15(4):2.

Falk, J., Attig-Bahar, F., Colwell, R. R., Behera, S. K., El-Beltagy, A. S., von Braun, J., ... & Yasunari, T. (2022). Addressing our planetary crisis: Consensus statement from the presenters and International Advisory Committee of the Regional Action on Climate Change (RACC) Symposium held in conjunction with the Kyoto-based Science and Technology in Society (STS) Forum, 1 October 2021. Sustainability Science, 1-3.

Geels, F. W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., ... & Wassermann, S. (2016). The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014). Research policy, 45(4), 896-913.

Hölscher, K., Frantzeskaki, N., Kindlon, D., Collier, M. J., Dick, G., Dziubała, A., ... & van der Have, C. (2024). Embedding co-production of nature-based solutions in urban governance: Emerging co-production capacities in three European cities. Environmental Science & Policy, 152, 103652.

Haddad, C. R., & Bergek, A. (2023). Towards an integrated framework for evaluating transformative innovation policy. Research Policy, 52(2), 104676.
http://www.ecologyandsociety.org/vol15/iss4/art20/

Ferreira, J. J., Fernandes, C. I., & Ferreira, F. A. (2020). Technology transfer, climate change mitigation, and environmental patent impact on sustainability and economic growth: A comparison of European countries. Technological Forecasting and Social Change, 150, 119770.

IPCC, 2023: *Climate Change 2023: Synthesis Report.* Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647.

Janssen, M. J., Torrens, J., Wesseling, J. H., & Wanzenböck, I. (2021). The promises and premises of mission-oriented innovation policy—A reflection and ways forward. Science and public policy, 48(3), 438-444.

Kern, F., & Markard, J. (2016). Analysing energy transitions: combining insights from transition studies and international political economy. *The Palgrave handbook of the international political economy of energy*, 291-318.

Kishita, Y., Höjer, M., & Quist, J. (2024). Consolidating backcasting: A design framework towards a users' guide. Technological Forecasting and Social Change, 202, 123285.

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., ... & Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. Environmental innovation and societal transitions, 31, 1-32.

Kok, J. L. (2021). Understanding stakeholder synergies through system dynamics: integrating multi-sectoral stakeholder narratives into quantitative environmental models. Frontiers in Sustainability, 2, 701180.

Koundouri, P.; Theodossiou, N.; Ioannidis, Y.; Papageorgiou, H.; Papandreou, A.; Papadaki, L.; Stavridis, C. Accelerating Science-Driven Blue Growth via a Competitive Intelligence Cloud/HPC Platform for AI-Based STI Policy Making. Environ. Sci. Proc. 2022, 15, 68.

Koundouri, P., Alamanos, A., Devves, S., Landis, C., & Dellis, K. (2024). Innovations for Holistic and Sustainable Transitions. Energies, 17(20), 5184.

Kungl, G., & Geels, F. W. (2018). Sequence and alignment of external pressures in industry destabilisation: Understanding the downfall of incumbent utilities in the German energy transition (1998–2015). *Environmental innovation and societal transitions*, *26*, 78-100.

Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. Futures, 42(3), 237-246.

Luederitz, C. et al. 2017. Learning through evaluation – A tentative evaluative scheme for sustainability transition experiments. Journal of Cleaner Production 169: 61 – 76. https://doi.org/10.1016/j.jclepro.2016.09.005.

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research policy*, *41*(6), 955-967.

McCann, P., & Soete, L. (2020). Place-based innovation for sustainability. Publications Office of the European Union: Luxemburg.

McCrory, G., Sch, N., Apke, €, Holm, J., & Holmberg, J. (2020). Sustainability-oriented labs in real-world contexts: An exploratory review. https://doi.org/10.1016/j.jclepro.2020.123202

Meadows, D. H. (2008). Thinking in systems: A primer. Sustainability Institute.

Newcombe, R. (2003). From client to project stakeholders: a stakeholder mapping approach. *Construction Management and Economics*, *21*(8), 841–848. https://doi.org/10.1080/0144619032000072137

Normann, H. E. (2017). Policy networks in energy transitions: The cases of carbon capture and storage and offshore wind in Norway. *Technological Forecasting and Social Change*, *118*, 80-93.

Papadaki, L., Stavridis, C., Koundouri, P., Grypari, I., Kazbek, M., Papageorgiou, H., & Theodossiou, N. (2023). Preparatory living lab workshops under the IntelComp platform: An enabler of the solution for sustainability challenges of climate change in Greece. *Frontiers in Environmental Economics*, *2*. https://doi.org/10.3389/frevc.2023.1100493

Quist, J. (2007). Backcasting for a sustainable future: the impact after 10 years. Eburon Uitgeverij BV.

Sharp, D., Raven, R., & Farrelly, M. (2024). Pluralising place frames in urban transition management: Net-zero transitions at precinct scale. Environmental Innovation and Societal Transitions, 50, 100803.

Tiller, R. G., Destouni, G., Golumbeanu, M., Kalantari, Z., Kastanidi, E., Lazar, L., ... & de

van Daalen, K. R., Romanello, M., Rocklöv, J., Semenza, J. C., Tonne, C., Markandya, A., ... & Lowe, R. (2022). The 2022 Europe report of the Lancet Countdown on health and climate change: towards a climate resilient future. The Lancet Public Health, 7(11), e942-e965.

Voytenko, Y., McCormick, K., Evans, J., & Schliwa, G. (2016). Urban living labs for sustainability and low carbon cities in Europe: Towards a research agenda. Journal of cleaner production, 123, 45-54.

Wittmayer, J. M., Schäpke, N., van Steenbergen, F., & Omann, I. (2014). Making sense of sustainability transitions locally: how action research contributes to addressing societal challenges. Critical policy studies, 8(4), 465-485.

Case study	Location	Title		
Case study #1	Athens, Greece	Mitigating urban heat through nature-based solutions		
Case study #2	Piraeus port, Greece	Mediterranean Ports Impact of climate change on ports infrastructures and operations		
Case study #3	Main river	Water-Energy-Food nexus		
Case study #4	Prespa lakes, Greece	Impact of water scarcity on water levels		
Case study #5	Canary Islands	Impact of temperature raise on the Water-Food nexus		
Case study #6	Black sea	Integrated water resources management from source to sea		
Case study #7	Southern Denmark	Emergency preparedness plan in flooding extremes		

Case study #8	Torbay & Devon country	Cascading effects on infrastructures during flooding		
Case study #9	Sardinia, Italy	Transforming the food production system based on durum wheat		

__________ New part