

## The role of sustainability living labs in understanding food-water-energy nexus challenges and solutions in India and Jordan

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## List of Abbreviations

CRELE	Credibility, Relevance, Legitimacy
FUSE	Food Water Energy for Urban Sustainable Environments
FUSE-SLL process	FUSE Sustainable Living Lab process
FWE	food-water-energy
LLs	Living Labs
NGOs	Non-Governmental Organisations
RWLs	Real-World Laboratories
SLLs	Sustainability Living Labs
TD	transdisciplinary
ULLs	Urban Living Labs
WBGU	German Advisory Council on Global Change

## Abstract

There are a multitude of challenges confronting resource-limited, rapidly growing cities that revolve around food-water-energy (FWE) resource issues, and there are a multitude of potential solutions. But such solutions often address one or just a few challenges without regard to their impacts on the entire FWE system.

We report on an innovative stakeholder engagement concept that links a living lab approach with the development of an integrated multi-agent urban-FWE systems model for two study regions: Pune, India and Amman Jordan. The model captures connections and feedbacks among the FWE sectors and aims to support long-term policy planning for a more sustainable and equitable provision of food, water and energy. In this context, knowledge of local stakeholders with regard to the FWE nexus is key. Moreover, stakeholder participation increases the chance that the model results are useful for and therefore used by policy makers and other relevant stakeholders, and consequently that the model supports efforts for achieving greater equity and sustainability in the FWE-nexus sectors. We have implemented a two-stage sustainability living lab process (2SLL), embedding several characteristics of existing living lab approaches, and adapting it to the requirements of our effort in Jordan and India.

This paper presents the objectives of stakeholder engagement within FUSE, differentiating between model-related and process-related objectives, and discusses requirements for reaching those objectives: First, workshop preparation was key. For one to two months, members of our team were in the study regions, and were able to select a representative cross section of workshop participants. Second, professional facilitation of the workshops was essential in bringing together stakeholders from many different sectors with scientists from different disciplines, and for creating an environment in which the stakeholders were able to formulate their food-water-energy challenges and to propose solutions. Third, an interdisciplinary research team was essential to be able to translate workshops results into inputs for different parts of the systems model.

We conclude that the 2SLL process shares many of the characteristics of the classical living labs, such as collaboration between scientific and societal actors, embeddedness in real-world contexts and use of experimentation and learning. However, the 2SLL process adds to these approaches by engaging stakeholders to co-formulate the model and ultimately evaluate the viability of solutions aimed at meeting the multitude of present and future food-water-energy challenges.

**Keywords:** food-water-energy nexus, multi-agent modelling, urban sustainability, living labs, sustainability living labs, urban living labs, transdisciplinary research, policy evaluation, stakeholder engagement, systems modelling

# 1 Introduction

Accelerating urbanisation presents a major challenge for societies, particularly those in the Global South. The provision of food, water, and energy (FWE) for increasing urban populations is essential to secure decent living conditions. While policy-makers are often absorbed with tackling imminent crises including distress caused by floods, droughts, food price hikes or power outages, strategies to mitigate long-term problems of resource supply such as FWE resource depletion, depletion of non-renewable resources, equal access to food or sustainable energy provision often fall behind (Rasul 2016).

Our research aims to address challenges linked to FWE nexus resources by developing an integrated multi-agent urban-FWE systems model. The model is used to explore the viability of future policy interventions aimed at overcoming short-term FWE vulnerabilities (cf. Turner et al. 2003) and improving prospects for long-term FWE sustainability (cf. Biggs et al. 2015). Geographically, we focus on the metropolitan regions of Pune in India and Amman in Jordan. The research brings together natural and social scientists, modellers, and stakeholder engagement experts from different institutions and countries. In a broad sense, our research strives to understand the FWE nexus challenges and to find solutions for both study regions. Acknowledging the complexity of the FWE nexus, the research takes place in a transdisciplinary setting and is based on the engagement of local stakeholders. To this end, a novel two stage sustainability living lab (2SLL) process was designed to reach model-related and process-related objectives of the research. It includes characteristics of existing living lab approaches, adapting them to the requirements of the research. While the 2SLL process embraces and guides the whole research, it entails two focal points in form of sets of workshops in Pune and Amman. Guided by the notion of living labs, these sets of workshops – at the beginning and close to the end of the research – are essential and decisive for the research's success<sup>1</sup>.

This Working Paper discusses the research's progress in integrating local knowledge on FWE nexus challenges and solutions in Pune and Amman in the development of an integrated systems model. It thereby focuses on the role of the 1<sup>st</sup> stage Sustainability Living Labs (SLLs) as a focal point in the process. To this end, the remainder of this paper is structured as follows. In Section 2, we contextualize the 2SLL process theoretically and conceptually. We point out why the investigation of complex societal problems such as the provision of FWE resources needs a transdisciplinary research setting. We further elaborate on the role of stakeholder engagement in such settings and deepen the understanding of living labs as an approach for stakeholder engagement. Section 3 describes the specific model-related and process-related objectives and requirements of the project and the 2SLL process. Section 4 reflects on how these objectives and requirements were met. Section 5 provides our conclusions.

## 2 Transdisciplinarity, stakeholder engagement and living labs

The FWE nexus is a complex and important issue due to the (i) interconnection and interdependence of the nexus areas and human-environment interactions, (ii) the importance of those systems for human survival, (iii) vested interests of various actors on decisions within nexus areas, and (iv) the uncertainty of possible future developments depending on external driving forces (Howarth/Monasterolo 2017; Kurian 2017).

To understand the complexity and non-linearity of human-environment interactions within the FWE nexus, a **transdisciplinary research process** is required. Transdisciplinary research is increasingly acknowledged as a precondition for achieving global sustainability, driven by the

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<sup>1</sup> As of May 2021, the research is in the midst of integrating and finalizing the systems model. The first set of workshops took place in February (Pune) and March (Amman) 2019. The second set of workshops are planned for autumn (Amman) and the end of 2021 (Pune). The dates are dependent on the Covid-19 situation in those countries.

urgency of problems and the need for the research to be socially relevant for real-world challenges (Jahn et al. 2012; Lang et al. 2012; Scholz/Steiner 2015; Sugiyama et al. 2017).

Transdisciplinary research can be defined as a research process that transcends disciplinary boundaries and integrates different types of scientific knowledge with non-scientific knowledge from fields to which the research relates (Bammer 2013; Bergmann et al. 2005; Howarth/Monasterolo 2017). Transdisciplinary research addresses real-life problems and aims to shape real processes, and therefore has to take into account local framework conditions.

As the interaction with different actors/groups of society is an essential characteristic of transdisciplinary research, suitable methods for interaction and knowledge integration must be developed and applied (Bergmann et al. 2005). Hence, **stakeholder engagement** is an integral part of transdisciplinary research. Broadly speaking and in a scientific context, a stakeholder is any person or group who influences or is influenced by the research (Durham et al. 2014). Science as such cannot solve or even define complex societal problems as they unfold in the context of sustainability research (e.g., natural resource management, ecosystem services, FWE nexus). To be able to come up with meaningful statements and viable solutions, science needs to include the perspective of those who know about the problems, i.e., stakeholders. The inclusion of local knowledge and information can enhance the quality of a project by assisting in better framing the problem at hand. Moreover, stakeholders may have access to data or other information, which they can share with the research team (ibid.; Luyet et al. 2012; Reed 2008).

However, stakeholder engagement does not come without challenges. For instance, there is the longstanding “concern that stakeholder engagement is not living up to many of the claims that are being made” (Reed 2008: 2420). Stakeholder engagement is time and resource consuming on all sides and does not take place in a power vacuum (Luyet et al. 2012; Reed 2008). Because of the latter stakeholders can be misrepresented, power asymmetries fostered and hierarchies among stakeholders reproduced. Stakeholder fatigue occurs when participants gain the feeling that they receive little in reward for their time spent, when their input is not taken up, and when stakeholder engagement is not well managed (Gramberger et al. 2015).

**Credibility, Relevance, Legitimacy** (CRELE) have often been proposed as criteria to assess, whether projects at the science-policy interface<sup>2</sup> achieve their intended impacts (Heink et al. 2015; Koetz et al. 2012). Ideally, they are already considered when setting up the research project and process. *Credibility* means that the information is perceived to be scientifically adequate, that the sources are authoritative and trustworthy (Dunn/Laing 2017; Farrell et al. 2006) and the quality of the research process itself is adequate (Durham et al. 2014). *Relevance*, sometimes also called salience, means that the knowledge created is useful and usable for stakeholders<sup>3</sup>. Legitimacy refers to the information development process and its outcome being unbiased and respectful of divergent stakeholder beliefs and values (Dunn/Laing 2017). A balanced group of stakeholders and facilitators that are impartial are important for legitimacy (Durham et al. 2014).

To achieve CRELE, it is important to view stakeholder engagement as a process that involves various steps, tasks and decisions. This includes the selection of an engagement approach, which meets the objectives and the requirements of the research. **Living Labs** represent such an approach. The concept was originally developed in the 1990s to promote user-centred innovation, often related to information and communication technology (Hossain et al. 2019). In the past decade, the concept of living labs spread to other policy fields that require involvement of a broad range of stakeholders and perspectives to tackle complex problems.

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<sup>2</sup> Science-policy interfaces can be understood as “social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making” (van den Hove 2007: 815).

<sup>3</sup> Usefulness means “provision of knowledge in forms and at temporal and spatial scales that fit with user practices and needs”; usability refers to the “accessibility of the information to policymakers and other stakeholders” (Heink et al. 2015: 679).

These are in particular fields related to sustainable development, such as energy, mobility, or social practices (Schäpke et al. 2018; Voytenko et al. 2016). Several sub-types have emerged in the past years, among them are *Sustainability Living Labs*, *Urban Living Labs*, *Real-World Laboratories* (e.g., McCrory et al. 2020; Menny et al. 2018; Schäpke et al. 2018). As they evolve through practice, so do their definitions (see Box 1).

Schneidewind et al. (2016) consider the approach of living labs as an 'ideal' type of **transformative science**, which they define as "a specific type of science that does not only observe and describe societal transformation processes, but rather initiates and catalyses them. Transformative science aims to improve our understanding of transformation processes and to simultaneously increase societal capacity to reflect on them" (ibid.: 6).

### *Box 1: Definitions of lab approaches*

**Living Labs (LLs)** in their original form have a strong focus on technological innovation, in which user-based knowledge serves as the main tool for commercialisation of such innovation (Almirall et al. 2012). "A living lab (LL) is an experimental research setting embedded in a real-world context. In LLs, researchers, users, and other stakeholders along the value chain co-create innovative products and services" (Schäpke et al. 2018: 88). According to Edwards-Schachter et al. (2012), characteristics of LLs are *innovation settings, operating environments, influence on innovation processes, user engagement, and expected outcomes*.

While building on the LL approach, the concept of **Sustainable Living Labs (SLLs)** recognizes that sustainable lifestyles cannot be achieved through technological innovations alone, but need to be embedded into social practices and routines. Liedtke et al. (2015: 107) define a SLL "as a *locally based regional, national and international infrastructure set-up to enable innovation processes in which users and value chain-relevant actors actively participate in development, testing and marketing phases*."

The term **Urban Living Labs (ULLs)** was introduced by the Joint Programming Initiative Urban Europe (JPI 2013: 13). ULLs serve as "a *forum for innovation, applied to the development of new products, systems, services, and processes, employing working methods to integrate people into the entire development process as users and co-creators, to explore, examine, experiment, test and evaluate new ideas, scenarios, processes, systems, concepts and creative solutions in complex and real contexts*." The labs bring together multiple actors, foster learning through experiments and aim to overcome current challenges as well as deliver sustainable goals in an urban context (Bulkeley et al. 2016). City governments typically act as prominent partners in ULLs, making them a forum for experimental urban governance (Schäpke et al. 2018). Voytenko et al. (2016) defined the following key ULL characteristics: *geographical embeddedness, experimentation and learning, participation and user involvement, leadership and ownership, and evaluation and refinement*.

Finally, **Real-World Laboratories (RWLs)** have recently gained prominence – especially in the German-speaking area. The German Advisory Council on Global Change (WBGU) defines RWLs as "transformative research approaches, involving scientifically designed spaces of collaborative sustainability research involving intervention" (WBGU 2016: 512). Schäpke et al. (2018) identify five characteristics of RWLs: *contribution to transformation, experimental methods, transdisciplinary research mode, long-term orientation, scalability and transferability of results, as well as scientific and societal learning and reflexivity*.

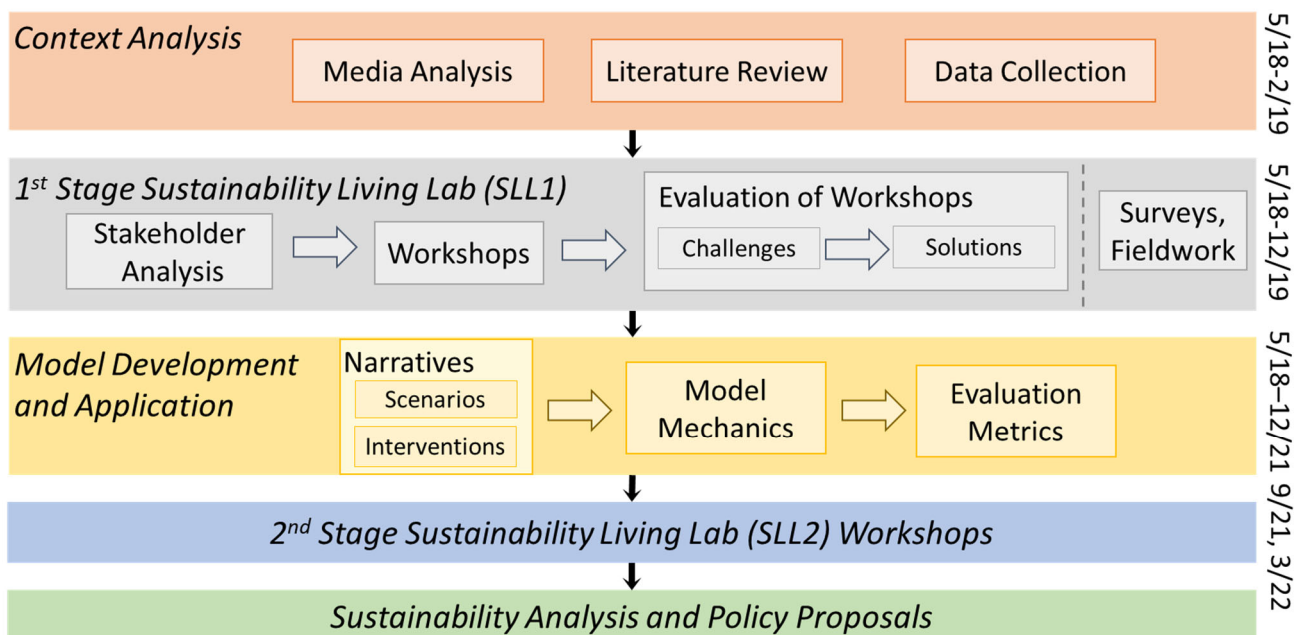
Although no universal definitions exist for the different forms of labs, three common characteristics have been deduced by examining different labs implemented in the recent years (e.g., Schäpke et al. 2018): 1) collaboration between scientific and societal actors, 2) embeddedness in real-world/local contexts, and 3) use of experimentation and learning. Although there is a broad literature on the characteristics of various living lab concepts, there is a lack of systematic discussion of their embedment into stakeholder engagement processes and transdisciplinary research. In addition, little is said about their application in developing systems models. Our research contributes to these debates by introducing an innovative process that adapts the living labs approach to the requirements of developing a systems model and to the goals of transdisciplinary research.

### 3 The 2SLL-Process

We report on an innovative SLL concept, the 2SLL process that links the Urban Living Lab approach (see Box 1) with the development of an integrated multi-agent urban-FWE systems model (Figure 1). The model consists of interacting modules and captures connections and feedbacks among users, producers, distribution mechanisms, and resources. Under scenarios of future changes in climate, demographics, land use, and economic development, policy interventions and innovative governance forms can be developed and evaluated to identify implementable sustainability options, such as tariffs, regulations, incentives or infrastructure. The model aims to support long-term policy planning for a more sustainable and equitable provision of food, water and energy. In order to develop the model and its components, local knowledge about challenges, problems and solution with regard to the FWE nexus and policy strategies is key. Moreover, stakeholder participation increases the chance that the model results are useful for and therefore used by policy makers and other relevant stakeholders, and consequently that the model supports efforts for achieving greater equity and sustainability in the FWE-nexus sectors.

As a specific approach for stakeholder participation, we developed the 2SLL process. It aims to understand stakeholder FWE challenges and to adopt a form of co-creation in which we design a systems model to address these challenges. Although the stakeholder engagement process spans the full duration of the project, it features two central living lab focal points, namely, one set of workshops in the beginning (1<sup>st</sup> Stage Sustainability Living Lab) and one set close to the end (2<sup>nd</sup> Stage Sustainability Living Lab) of the project duration. These focal points serve to bookend systems model formulation and development. The 1<sup>st</sup> and 2<sup>nd</sup> stage SLLs deserve special attention, since they are central to the progress and eventual success of a stakeholder-based project. However, the design and implementation of these focal points can only be understood in the wider context of the 2SLL process and its objectives. In what follows, we concretize the objectives of stakeholder engagement. In the context of the CRELE approach and stakeholder engagement literature, we point out the requirements to meet those objectives and describe the components of the 2SLL process.

Figure 1: 2SLL process



Source: Own elaboration, first cited in Klauer et al. (in preparation)  
 Note: Surveys and fieldwork only took place in Pune, India.



### 3.1 Objectives and requirements with regard to the stakeholder engagement in the 2SLL process

Referring to stakeholder engagement literature (e.g., Reed 2008) and the CRELE concept (Heink et al. 2015; Koetz et al. 2012), our objectives with regard to stakeholder engagement using the 2SLL process are two-fold. They can be differentiated into **model-oriented objectives**, which are necessary for the model development, and **process-related objectives**, which contribute to the credibility and the relevance and therefore the transformative character of the research.

#### *Model-related objectives*

The involvement of stakeholders is essential for systems **model** development. Hence, the objectives of the 1<sup>st</sup> Stage Sustainability Living Labs were (1) to collect stakeholders' perspectives, interests, challenges, coping strategies, needs, and visions in relation to the FWE nexus; (2) to better understand the functioning and complexity of the regional FWE systems, their political economy, constraints and driving forces to develop feasible policy interventions and to better understand interlinkages and trade-offs between the FWE sectors, (3) to develop long-term oriented narratives (consisting of scenarios involving climate change, population growth, and socio-economic scenarios over which the region has essentially no control, and policy interventions that the region has the ability to implement) based on stakeholders' needs and visions.

For the 2<sup>nd</sup> Stage SLLs, the main objective is to use modelled policy-evaluation results as the basis for discussion with stakeholders to solicit impressions regarding the model results, the underlying model assumptions, and the benefits and practicality of developed narratives and solutions.

#### *Process-related objectives*

Besides these model-related objectives, the 2SLL process also encompasses process-related aims, which address the transformative character of the research:

To develop legitimate, credible and relevant research results, the **2SLL process** aims to: (1) foster understanding between researchers and local stakeholders from different sectors (2) assure the usability and buy-in of the model in order for it to provide a valuable future planning and decision-making tool that is employed e.g., by government agencies or non-governmental organisations (NGOs), (3) initiate a local network for exchanging and establishing lasting relations between the actors, perhaps for further collaboration and (4) have a positive impact that goes beyond the project period by promoting interventions that are likely to enhance sustainable development of the FWE nexus.

In the context of the above aims, specific **requirements** for the 2SLL process are: (1) a research team with different disciplinary and interdisciplinary backgrounds, including team members with professional facilitation skills (cf. Durham et al. 2014; Gramberger et al. 2015; Reed 2008); (2) systematic inclusion of different stakeholders, selected from urban citizens, farmers, civil society, small companies, and policy experts, ideally gender and age balanced from all FWE sectors, to ensure multi-level perspectives (Reed et al. 2014; Talley et al. 2016); (3) an approach and workshop environment that creates a safe space with an atmosphere of trust to enable the exchange of opinions, experiences and ideas, and to leverage the unique expertise of stakeholders (cf. Reed 2008; Schoonover et al. 2019); (4) adequate methods that allow for eliciting information relevant for the systems model formulation (cf. Luyet et al. 2012); (5) establishment of relationships with key stakeholders beyond the physical workshops who see value in working together and using the systems model as part of their future policy-evaluation and planning process. Collectively, those requirements reflect the special intermediary character of the SLL process to create mutual understanding and buy-in for the research and strengthen the transformative character by having an impact in the study regions.

### 3.2 Components of the 2SLL process and the role of 1<sup>st</sup> stage SLLs

To meet the requirements and building on existing living lab approaches, we developed the 2SLL process. It includes a context analysis, stakeholder analysis, stakeholder selection, and two series of workshops in each city, at the beginning (1<sup>st</sup> stage 2SLLs) and close to the end of the project period (2<sup>nd</sup> stage 2SLLs) (see Figure 1), along with collecting survey data and obtaining further input from regional experts. In the 1<sup>st</sup> stage, we conducted three targeted, separate workshops for both case studies involving civil society and local actors, experts from government, academia and industry, and NGOs, as well as process modelling and technical experts. The 2SLL process is consistent with Schöpke et al. (2017: 85) that: “Setting up a laboratory within society requires the adaptation of methods and procedures to specific contexts, actors, and issues”

After and while acquiring an understanding of the structure and the political economy of FWE systems in Pune and Jordan, stakeholders within the different sectors were identified, and further classified according to the degree to which they are capable of influencing (power) or are affected by (interest) challenges within the FWE systems. The research team closely cooperated with a partner organization in each region, which helped to identify and to establish contacts to key stakeholders and who also handled the logistics and played an active role in the workshops. Two project members went to the case study places for more than one month before the respective workshops in Pune and in Amman to identify and get to know potential stakeholders. Furthermore, there was intensive on-site data collection by team members, and maintenance of relationships with those who expressed interest in the aims of the project or in supporting it by providing data and expert information.

The first stage of SLLs consisted of three workshops. The first workshop (“affected stakeholder workshop”) gathered about 35 participants from farmers’ organisations, citizens’ associations, NGOs working on environmental and urban issues, and small companies. In the course of one day, the group elicited current and future FWE challenges, coping strategies and solutions. After the first workshop, the team processed the results of the stakeholder workshop with a focus on collected challenges and their relevance in the FWE sectors in the urban context. The second workshop (“expert workshop”) assembled about 45 participants from academia, public institutions, and former government officials as well as individuals from various parts of the private sector. Using the results of the first workshop as a starting point, participants cross-checked the expressed challenges and proposed policy solutions. As a key component of the second workshop, participants co-created a vision for a sustainable Pune and Greater Amman region, respectively, in 2050 and developed strategies on how their vision could be accomplished given future challenges. Finally, a smaller workshop with participants who specialise in quantitative modelling was held to obtain feedback on connections and feedbacks represented in the integrated system model.<sup>4</sup>

Since the first set of workshops, further exchange with stakeholders has taken place both physically and virtually. Several field research trips to Pune and Amman served collaborative quantitative and qualitative data collection in surveys, focus group discussions and interviews. In January 2020, a workshop was held to discuss preliminary results with stakeholders in Pune, and in spring 2021, a joint 2-months internship project between our local research partner and the FUSE project, has begun. Update calls, regular stakeholder newsletters and an up-to date project website complement the information flow.

The 2<sup>nd</sup> stage workshops are planned for the second half of 2021 and beginning of 2022 respectively<sup>5</sup>. The results from the policy-evaluation model will be presented to the participants of the first workshops and other stakeholders, and feedback will be elicited, which will feed into the refinement of the model.

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<sup>4</sup> The workshop documentation can be downloaded from the website (<https://fuse.stanford.edu/publications>).

<sup>5</sup> Unfortunately, the COVID-19 pandemic did not allow the team to return to Pune and Amman at the end of 2020 for the 2<sup>nd</sup> stage FUSE-SLLs as planned.

## 4 Preliminary observations and insights

We present a novel approach that draws on the CRELE concept as the starting point for developing the 2SLL process, adopting and further developing key characteristics of living lab approaches in the broader framework of transdisciplinary research and stakeholder engagement. The main characteristics adopted are: collaboration between scientific and societal actors, the embeddedness in the real world/local context, and eliciting different forms of knowledge through the experimental nature of the SLLs. In the following, we discuss how our approach met the objectives and requirements set forth above, namely to collect inputs for the model development and to ensure credibility, relevance and legitimacy of the project in order to have an impact that extends beyond the project period.

The first set of workshops was able to meet the model-related objectives. The workshops resulted in a collection of numerous challenges of the urban FWE nexus, as well as of possible policy solutions and strategies (Karutz et al. 2021, Klauer et al. in preparation) that are essential inputs to systems model-development. The workshops and further interaction with the stakeholders increased the team's understanding of the political economy of the FWE nexus (Lee et al., 2020). The visions and policy solutions are integrated in the narrative development. Over the two years between the 2SLL stages, the workshop results have been further processed, combined with data from published literature, reports and surveys, and integrated into different components of the systems model. The final model-related objective (discussing the policy evaluation results) will be the centrepiece of the second set of workshops.

The process-related aims guided stakeholder engagement. By spending up to two months before the workshops in the study areas, team members could get to know many stakeholders personally and were invited to participate in meetings and workshops on FWE issues organised by different stakeholders. This helped us to learn about local challenges and current policy debates, to create mutual trust and facilitated sharing of personal experiences and opinions during the workshops. Further, the fact that the majority of the project team members came to Pune and actively participated in the workshops increased credibility and acceptance of the project. Cooperation with stakeholders continued after the workshops, in terms of e.g., collaborative data collection.

To reach the model- and process related objectives, the 2SLL process shares many of the characteristics of the classical living labs, such as collaboration between scientific and societal actors, embeddedness in real-world contexts and use of experimentation and learning. However, the 2SLL approach adds to existing concepts by focussing on overcoming challenges related to the FWE nexus by co-developing feasible and legitimate future policy interventions that increase human and environmental well-being with stakeholders, whose long-term impacts can be evaluated with a region-specific systems integrated model. The model enables a long-term impact of the research, which is potentially transformative, if the model is used by stakeholders to make better-informed FWE policy decisions. The process of co-developing challenges and solutions during the workshops coupled with the ability to evaluate different policy solutions in the model demonstrate the experimental character embedded in the 2SLL process.

By bringing together stakeholders from many different sectors and segments of society with scientists and engineers from different disciplines, mutual understanding for each other's challenges and visions could be enhanced, which points to the intermediary character of the 2SLL process (Hossain et al. 2019). Careful design of the methodology and professional facilitation were essential to creating a safe space that allowed stakeholders to share ideas and solutions and to reduce the distance between researchers and stakeholders. The process has also helped to create buy-in for the research. A combination of high-level support (for instance from former and current Ministers) and relations with grassroots organisations (e.g., closely working with farmers and slum organisations) has been important in this respect.

A reflection of our 2SLL process and the role of the 1<sup>st</sup> stage of SLLs, however, would not be complete without a critical reflection of the framework conditions. Our research focusses on India and Jordan. The research team consists of researchers based in Austria, Germany, and the USA, as the funding structure only allows for funding personal costs for institutions in countries participating in the funding programme. Ideally, research partners from the study regions and important stakeholders should be included in the project already from the proposal writing and the design phase (Lang et al. 2012). Additionally, as in many projects, resources for stakeholder engagement in the project are limited. There is a high commitment among all team members – including the modelling team – to the stakeholder engagement process and its value. Nevertheless, most of the resources are attributed to the development of the model, with stakeholder involvement foreseen only at the beginning and the end of the model development process. We hope that the effort that has gone into the model development will lead to the adoption of a tool that is useful for local actors and can support decision making for a sustainable management of FWE resources.

## 5 Conclusions

Summarising, we can say the 2SLL process has the ingredients to be transformative and have an impact beyond the project. This is due to its embeddedness in a transdisciplinary research perspective and the selection of a living lab approach to stakeholder engagement. The 2SLL process brings together international expertise from different disciplines, embraces local knowledge and experience, and is developing an innovative policy-evaluation tool that helps local actors to identify solutions that reduce short-term vulnerability and promote long-term sustainability of FWE resources.

The design and implementation of the 2SLL process was able to reach the model-oriented and process-oriented objectives of the research. The workshops resulted in a collection of numerous challenges of the urban FWE nexus, as well as of possible policy solutions and strategies (Karutz et al. 2021) that are essential inputs for the modelling process. The preparation process and the workshops themselves that brought together stakeholders from many different sectors with scientists from different disciplines, enhanced mutual understanding, created credibility and legitimacy, and increased the possibility that project results will be relevant for local actors. Professional facilitation and the active and enthusiastic engagement of the whole team was key in this respect.

The 2SLL process takes place in a transdisciplinary research setting by bringing together a team of natural and social scientists from different disciplines, and stakeholder engagement experts, with stakeholders from different FWE sectors. It shares many characteristics with other living lab approaches, namely collaboration between scientific and societal actors, embeddedness in real-world contexts and use of experimentation and learning. However, the 2SLL process adds to the approaches by being designed in a way that model-related inputs are elicited. It is long-term oriented, and it aims to establish long-term relationships with important stakeholders to increase usefulness and usability of the model.

We note that to increase the transdisciplinary impact of this approach, local research partners with sufficient funding, and a more intensive stakeholder engagement process that spans the entire duration of the project and includes several exchanges during the project period, including the modelling phase, would be necessary.

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