

Urban Living Labs as a Driver for Sustainable Food-Water-Energy Innovations

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1 ABSTRACT

The Food-Water-Energy (FWE) nexus provides a useful frame for considering sustainable urban development, due to the inevitably close linkages among demand for energy, freshwater and food by the growing urban population, and the availability of these resources.

To facilitate sustainable development on a global scale, local and regional solutions concerning food, water and energy challenges need to be established and tested. The exchange of best practices and their potential transfer and upscaling should be fostered.

The project GLOCULL (Globally and Locally-sustainable Food-Water-Energy Innovation in Urban Living Labs) has been initiated by an international consortium to address the above-mentioned needs: to create evidence of potential solutions with respect to FWE nexus in seven Urban Living Labs, to share results and experiences, and to provide methodological and practical guidelines and recommendations, with a local and global scale outlook.

Urban Living Labs (ULLs) represent an experimental approach of university involvement in a real-world setting, where academic and non-academic actors, including local administration and stakeholders, collaborate on various urban development challenges. Despite the recognition of ULLs as a promising form of urban governance on the EU level (EU 2011), their successful implementation requires further evidence-based elaboration (De Kraker et al. 2016).

Each of the GLOCULL partners (the consortium includes: Maastricht University / Netherlands, Leuphana University Lüneburg / Germany, The University of Natural Resources and Life Sciences, / Austria, Arizona State University / United States, University of Sao Paulo / Brazil, Lund University / Sweden and Stellenbosch University / South Africa) has developed and implemented experiments focusing on local innovations in various aspects of the FWE nexus, within an ULL. The innovations have been co-created by universities and non-academic partners in each country, using transdisciplinary approaches, resulting in co-production of knowledge, shared with the international project partners. Moreover, flow- and causal-loop diagrams were used to integrate knowledge gathered through participatory, integrated assessments in each of the implemented experiments. The impacts of the project include: the academic impact through advancing knowledge on sustainability transitions through ULL in the FWE nexus and different economic and societal impacts. The latter provides evidence on the local and global sustainability of local food systems, the acceleration of the transition towards sustainable food system, the integration of the FWE nexus and related

inputs into decision-making and the contribution to practice partners (local individuals and organisations) through facilitating closer collaborative relationships, network-building and solution orientated approaches to their FWE challenges. Furthermore, the project is also focusing on capacity building. Practice partners are developing technical and personal skills, as well as individual and collective agency, and are sharing their practice and lessons institutionally. This should help to strengthen scholars-local actors-collaboration and co-production of knowledge.

An evaluation and case study reporting framework is being developed by the partners to reflect on and assess the implementation of each ULL and compare the process and outcomes across the seven ULLs. Moreover, local and international partner experiences will be synthesised into an implementation guide for practitioners and a participatory assessment toolkit. Keywords: sustainable urban development, urban innovations, transdisciplinary research, urban living lab, food-water-energy nexus

2 INTRODUCTION

2.1 The Food-Water-Energy (FWE) nexus

Addressing sustainable development inevitably requires understanding close interlinkages among ecological, economic and social aspects, as well as among the different resources, sectors and disciplines, and the actors involved. This paradigm is embodied on the global level by the 2030 Agenda for Sustainable Development Goals (UN 2015). The Food-Water-Energy (FWE) nexus provides a useful frame for considering such synergies among energy, freshwater and food resources.

The concept of the FWE nexus emerged after the energy and food crisis in 2007–2008, and has since been growingly embraced by the academic and policy community. It underlines the integrated and interactive links among food, water and energy resources, as components of one system, in order to maximize synergies, and minimize trade-offs among these sectors (Hoff 2011 in Wahl et al, 2021). Researchers to-date have identified several knowledge gaps with respect to implementing FWE nexus approaches, including the identification of real world solutions and pathways to action, considering different contexts and multiple scales (Leck et al. 2015 in Wahl et a. 2021). They have called for applying inter-and transdisciplinary approaches, engaging societal and non-academic actors (Scanlon et al. 2017; Simpson and Jewitt 2019) and addressing “innovation, social and political context, collaboration, and implementation in policy and practice” (Albrecht et al. 2018, p. 20, in Wahl et a. 2021). To facilitate sustainable development on a global scale, local and regional solutions concerning food, water and energy challenges need to be established and tested. The exchange of best practices and their potential transfer and upscaling should be fostered.

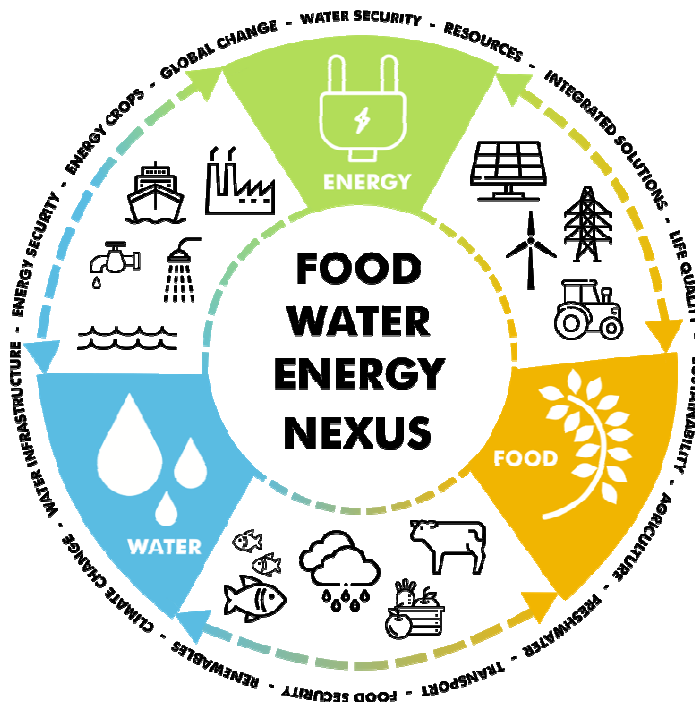


Fig. 1: Food Water Energy Nexus. Source : Own Illustration by Kim Ressar.

Application of FWE nexus on the urban level is particularly valuable in light of growing urban sustainability challenges. Along with increasing urbanization and resource consumption, cities are centers of economic activity, innovation and entrepreneurship (Fuenfschilling et al. 2019 in Wahl et a. 2021). Due to its increasing complexity, the urban context can help in understanding and managing the FWE nexus, while at the same time, application of the nexus approaches can serve to address urban sustainability challenges (Wahl et a. 2021).

2.2 The GLOCULL project

The project GLOCULL (Globally and Locally-sustainable Food-Water-Energy Innovation in Urban Living Labs) has been initiated by an international consortium to address the above-mentioned urban sustainability challenges. The consortium includes Maastricht University / Netherlands, Leuphana University Luneburg / Germany, The University of Natural Resources and Life Sciences, / Austria, Arizona State University / United States, University of Sao Paulo / Brazil, Lund University / Sweden and Stellenbosch University / South Africa. The partners were selected because of their expertise in transdisciplinary approaches. The partners aimed at: 1) creating evidence on potential urban sustainability innovations based on the framework of the FWE nexus and in the context of seven different cities, as well as 2) sharing results and experiences on the international level and, and 3) providing methodological and practical guidelines and recommendations, with a local and global scale outlook.

The project is organized into seven Work Packages (WPs), see Figure 2.

The given contribution presents the methodological approaches and results of the GLOCULL project to-date.

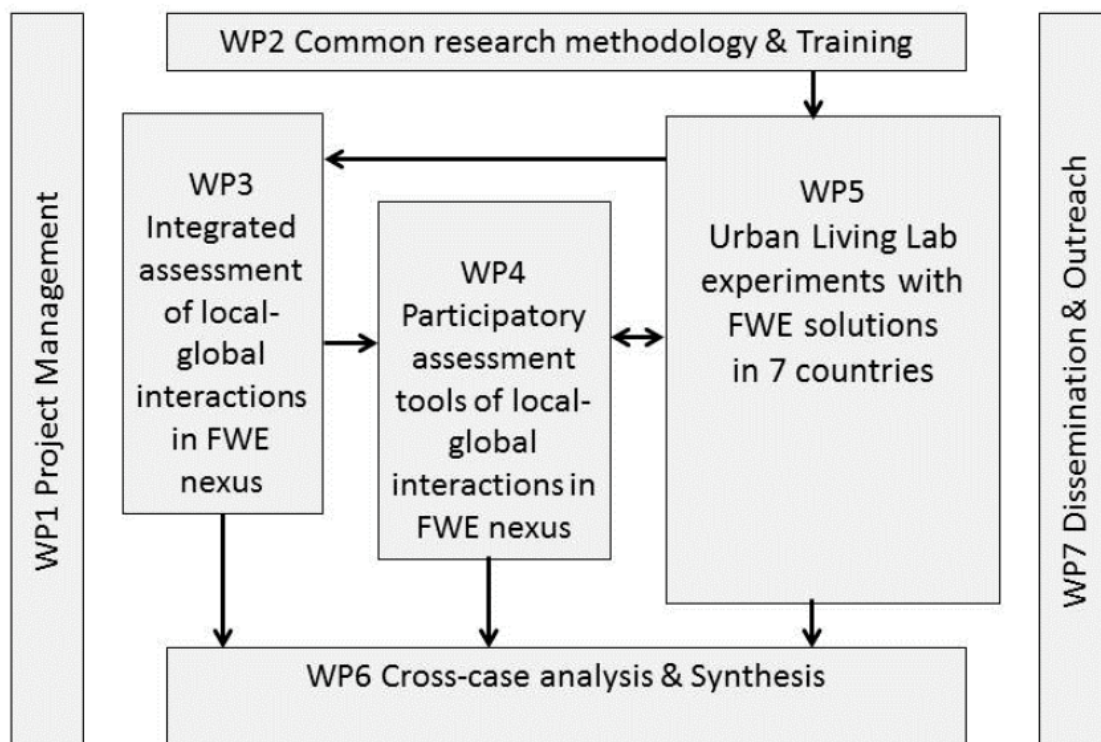


Fig. 2: GLOCULL project organization. Source:GLOCULL project.

3 MAIN APPROACHES AND METHODS

The GLOCULL partners agreed on the following approaches to implement the project:

- (1) Setting up Urban Living Labs and co-creation of local urban FWE innovations in close collaboration with local stakeholders, and co-production of knowledge using transdisciplinary approaches;
- (2) Participatory, integrated assessments, using flow- and causal loop diagrams to integrate knowledge gathered from implemented experiments. Synthesising local and international experience in implementation guidelines for practitioners and a participatory assessment tool kit;

(3) Designing and using an evaluation framework to reflect on and evaluate implementation of each ULL and compare the process and results among the 7 countries.

3.1 Urban Living Labs

The GLOCULL partners chose to implement Urban Living Labs (ULLs) - an experimental approach of university involvement in a real-world setting, where academic and non-academic actors, including local administration and stakeholders, collaborate on various urban development challenges. Despite the recognition of ULLs as a promising form of urban governance on the EU level (EU 2011), their successful implementation requires further evidence-based elaboration (De Kraker et al. 2016).

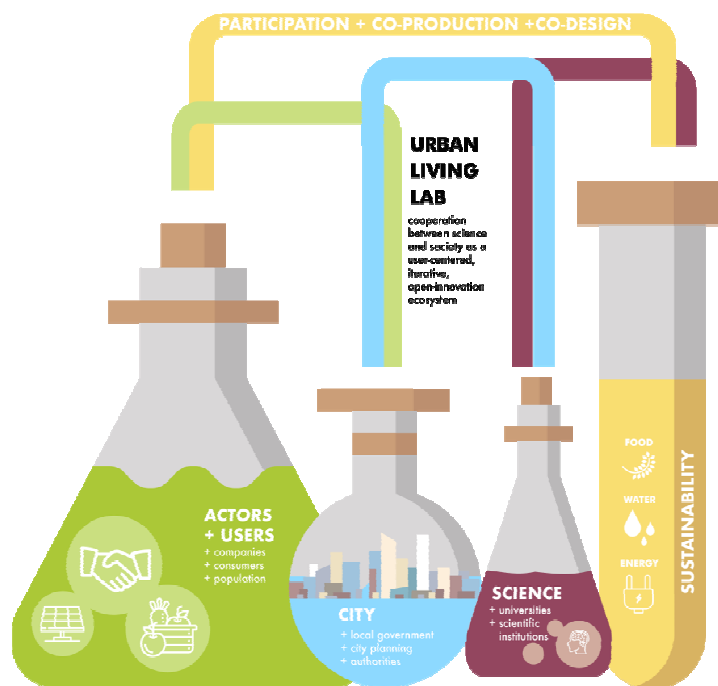


Fig. 3: Urban Living Labs Source: Own Illustration by Kim Ressar.

Each partner has set up an ULL and within these, developed and implemented experiments focusing on local innovations in various aspects of the FWE nexus. The innovations have been co-created by universities and non-academic partners in each country, using transdisciplinary approaches. The actors from outside academia have been involved from the design phase in each ULL, albeit in each case to a different extent, based on their level of availability. Flow- and causal-loop diagrams were used to integrate knowledge gathered through participatory, integrated assessments in each of the implemented experiments. The knowledge and results co-produced within each ULL have been regularly shared with the international project partners. Table 1 includes the name and brief description of each ULL.

3.2 Participatory Assessment Toolkit

Based on the partners' experience in using flow- and causal loop diagrams, to integrate what they have learned in collaboration with the stakeholders of each ULL, a Toolkit has been created, in order to help assess local and beyond-local-scale impacts of innovations on the FWE nexus.

The Toolkit combines the focus on local and beyond-local impacts. It enables its users to learn about the FWE nexus, to apply nexus-thinking to an innovation case of their choice and to jointly learn about the impacts of innovations on the nexus. Although it can be used by interested individuals, it is best suited to participatory (Living Lab) setting. The Toolkit has been designed in a way to facilitate evaluation of the impacts of innovations based on criteria and indicators that matter to the users, in order to emphasise joint learning and co-creation (and co-optimisation) of innovations.

After further testing the Toolkit in the seven GLOCULL Living Labs, it will be made freely available and accessible via the GLOCULL website (<https://glocull.boku.ac.at>), the Belmont Forum website and via Github, supplemented with a user manual.

Country	Partners	ULL Name	ULL Brief description
Austria	The University of Natural Resources and Life Sciences, Vienna (BOKU), NIKKO Photovoltaik (NP)	Agrivoltaics in urban / peri-urban areas	The ULL focuses on dual land use – coupling food and energy production. It tested potential for introducing Agrivoltaics to greenhouse vegetable production at the outskirts of Vienna, by mounting PV-panels on greenhouses of gardeners, members of the local vegetable producers’ association, and initiated a multi-stakeholder discussion process about the issues of societal acceptance, governance challenges and technical solutions for Agrivoltaics in Austrian urban agricultural areas.
Brazil	University of Sao Paulo	Local solutions for FWE nexus in São Paulo	The ULL aims to conduct a sustainability assessment, in a participatory fashion, of ongoing actions in the rural south zone of São Paulo, with a particular focus on the interdependence of the nexus systems and local characteristics. The ULL worked with the goal of validating the sustainability of municipal actions to support local agriculture by developing a set of indicators that can capture FWE interactions, existing conflicts and potential responses. The ULL accompanies the project “Ligue os Pontos” (LoP – or “Connect the Dots”), which main goals are to: i) contain urban sprawl by maintaining the farmers in the south zone of São Paulo, ii) promote sustainable agriculture practices, and iii) preserve natural ecosystems.
Germany	Leuphana University Lüneburg	Urban Sustainability Transformation 2030+	The ULL builds upon previous collaborations of Leuphana University, the City of Lüneburg and other actors to establish a Sustainability Living Lab, funded by the German Ministry of Education and Research since 2014. The Lab is supporting implementation of Lüneburg’s collaboratively developed vision of a sustainable community that meets its local and global responsibilities. This sustainability vision covers 25 topical areas, including food and energy in the local economy. A local food council as a novel governance body and a local-living economy that emphasizes local food production and consumption are among these measures. The ULL is supporting development of concrete measures to reach these visions.
The Netherlands	Maastricht University	Closing the FWE cycles at neighborhood level	The ULL is focused on the FWE nexus in the context of the SUPERLOCAL project in the Bleijerheide district in the City of Kerkrade, where a local housing corporation is working on replacing vacant high-rise buildings with high-quality but affordable low-rise housing in a sustainable manner. The ambition is to recycle and re-use all possible landscape elements, building materials, to introduce a close-loop water system, and to consider social sustainability with respect to the residents of the resulting neighbourhood.
South Africa	Stellenbosch University	Management of edible food waste in informal settlements	The ULL accompanies the establishment of a community garden and a fresh food market in a Khayelitsha township, located in the surroundings of Cape Town. It addresses challenges, such as food safety and access to food, as well as opportunities to enhance the system, and aims to enable better governance by formal and informal actors that would help Cape Town to further develop its economic, social and environmental objectives.
Sweden	Lund University, Bryghuset Finn	Sustainable urban Craft Beer Production	The SustBeerLab ULL is focused on tangible measures to increase the sustainability of craft beer production in selected urban areas in southern Sweden. The aim of the lab is to develop, physically implement and test novel solutions to sustainability challenges associated with craft beer production in the region. Within the FWE-nexus, several potential targeted solutions that integrate knowledge have been proposed and are explored in a co-creative process with the stakeholders.
USA	Arizona State University, City of Tempe, City of Phoenix, Local First Arizona	Developing sustainable local food system	The ULL focuses on learning about and facilitating community-based entrepreneurship and innovation at the food, water, energy nexus among the local business owners in City of Tempe and City of Phoenix. It comprised efforts to: (i) Identify catalytic actions that can be taken by different stakeholders to spur innovation, entrepreneurship, and investment at the (FWE) nexus; (ii) Assess and prioritize catalytic actions for the impact on decarbonization efforts, broader sustainability objectives, and public support. (iii) Design, test and implement capacity building experiments, located in Phoenix and/or Tempe, aimed at enabling stakeholders to take high priority, high impact actions.

Table 1: GLOCULL Urban Living Labs. More information can be found on the GLOCULL project website:

<https://glocull.boku.ac.at/>

The browser-based Toolkit (available at <http://bramoosterbroek.nl/GLOCULL/toolkit.html>) consists of three modules with various tools:

- Module 1 “Awareness and Opportunities” aims to acquaint users with the concept of the FWE nexus with the help of several multimedia items (e.g., videos, podcasts, and games). This module familiarizes users with thinking about FWE nexus as an integrated system, and identifying opportunities regarding saving resources, converting resources, gaining local sustainability benefits

or gaining benefits on another spatial scale. The tool provides basic guidelines on the available multimedia, to enable a quick choice of most relevant items for each user.

- Module 2 “System Overview” aims to account for the potential resource savings, efficient resource conversions, beneficial social, environmental and economic effects, as well as beyond-local effects. The Module 2 tool supports the creation of a FWE system’s diagram that enables an overview of a regional and local system, into which the user’s Living Lab innovation is embedded. The Tool, in the form of a PDF template, guides the users through several steps to (graphically) represent the FWE system in which their project is embedded, as well as to identify the beyond-local and sustainability impacts of their project. It also aids its users to pinpoint where innovation is possible, and identify direct and indirect beyond-local and sustainability impacts effects of a potential innovation. Last but not least, it facilitates comparison of system performance, such as the system with and without a set of interventions. A manual and examples, based on GLOCULL case studies, enable tool-users to develop their own FWE-system overview.
- Module 3 “Quantitative Assessment” aims to help users perform a quantitative Food-Water-Energy assessment and compare the current situation with a potential scenario in which an innovation is implemented. The Tool provides a Multi Criteria Analysis-based template (including scoring, standardisation, and weighting) for the quantitative assessment of two or more FWE scenarios, relevant to the user. It assists users in accounting for a comprehensive set of themes (for example food savings, impact on surroundings, social aspects) and indicators of an integrated FWE assessment. Moreover, it helps visualize the difference in how these themes are impacted between the situation prior to and after an innovation, using radar charts.

The quantitative assessment tool can both be fed with detailed data, but also with estimations (e.g. on a Likert-scale). The latter helps overcoming challenges in cases where quantitative data are hard to retrieve. Case study files based on the GLOCULL Living Labs are presented in the same file format as the tool, and can be downloaded from the toolkit.

Dimension	Level	General Description
Setting	Context	What are the general contextual factors that significantly influence the overall purpose of the lab or the specific design, outputs, or outcomes of the experiments the lab conducts?
Spatial and temporal scope	Lab	What is the spatial scope of the lab?
Process		What is the Lab’s procedural design?
Organization		How is the Lab organizationally structured?
Sustainability		What is the Lab’s general sustainability orientation?
Outputs	Experiment	What changes were generated, inside or outside the lab, as a direct result of the experiment?
Outcomes		How did the experiment contribute to sustainability of society, both within and beyond the immediate scope of the Lab?
Processes		How was the experiment designed and conducted?
Inputs		What are the enabling factors of the experiment?

Fig. 4: GLOCULL Case Reporting Scheme. Source: GLOCULL Project (based on Forrest et. al., 2019, Luederitz et. al. 2017, Schöpke et. al. 2018,)

3.3 Case study reporting scheme

A case study reporting scheme has been developed by the partners to reflect on and assess the implementation of each ULL and compare the process and outcomes across the seven ULLs. The aims of the reporting scheme include: 1) helping the partners capture the work conducted by the transdisciplinary teams within the ULL, 2) facilitating reflection on the implementation of the sustainability-oriented experiments conducted in the ULLs, 3) structuring the reporting on these collaborative activities and 4) providing more comprehensive understanding of the development and the impacts of sustainability solutions in such settings.

The partners are in the process of testing the scheme based on their respective ULLs, and will update the scheme based on this experience, in order to render it applicable beyond the GLOCULL project to 1) support

Tamara Mitrofanenko, Andreas Muhar, Kim Ressar, Thomas Schauppenlehner, Astrid Offermans, Darin Wahl, Barry Ness, Philip Bernert, Michele Dalla Fontana, Fabiano de Araújo Moreira, Gabriela Marques Di Giulio, Tadeu Fabrício Malheiros researchers and practitioners to explore their own projects and 2) facilitate generating a growing knowledge base on sustainability-oriented experiments and transfer of knowledge between experiments conducted in different contexts. The reporting scheme is structured following a basic logic model of context, laboratory and experiment/s (see Figure 4).

4 MAIN RESULTS AND IMPACTS

The impacts achieved by the project include:

- Advancing academic knowledge on sustainability transitions through ULL in the FWE nexus.
- Capacity building of academic and practice partners, through development of technical and personal skills, individual and collective agency, and sharing practice and lessons institutionally.
 - The GLOCULL partners have achieved joint learning about, and increased interest in, the FWE nexus across stakeholders that were not so much interested in, or aware of, nexus issues before. More awareness is expected to lead to increased support for innovations that are sustainable across the nexus among politicians (e.g. by prioritizing nexus issues as is happening in the USA already), policy makers (in Brazil), and consumers (in South Africa, Austria, the Netherlands, Sweden and Germany).
 - The Tools created by the project can be used by stakeholders in Living Labs, in collaboration with researchers, beyond the GLOCULL project and after the finalization of the project, to help them learn about the FWE nexus plan and assess innovations, as well as optimize synergies in the FWE-nexus.
- Advancing sustainable solutions or innovations at the ULL level. Various economic and societal impacts in the individual ULLs, including:
 - Collecting evidence on the local and global sustainability of local food systems,
 - Acceleration of the transition towards sustainable food system,
 - Integration of the FWE nexus and related inputs into decision-making,
 - Contribution to practice partners (local individuals and organisations) through facilitating closer collaborative relationships, network-building and solution orientated approaches to their FWE challenges.

Table 2 outlines more specific impacts in each ULL.

Country	ULL Name	Impact
Austria	Agrivoltaics in urban / peri-urban areas	Providing the evidence base and fostering public discussion about the importance of agrivoltaics in urban / peri-urban areas; Making inputs into policy to support dual use of agricultural land
Brazil	Local solutions for FWE nexus in São Paulo	Application of sustainability indicators related to the FWE nexus on the digital platform of the city of São Paulo, Brazil
Germany	Urban Sustainability Transformation 2030+	Supporting local businesses to introduce changes in food (ex. local non-dairy milk) and clean energy supply to foster a sustainable local economy in Lüneburg, Germany
The Netherlands	Closing the FWE cycles at neighborhood level	Facilitating introduction and settlement of “re-cycled” and sustainable housing with a closed local water cycle in Kerkrade
South Africa	Management of edible food waste in informal settlements	Establishment of an urban garden in a school yard, and a fresh produce market in an informal settlement of Khayelitsha in Cape Town
Sweden	Sustainable urban Craft Beer Production	Garnering interest and feedback through experiment trials, especially from plant scientists, farmers, and craft beer brewers in Sweden
USA	Developing sustainable local food system	Building local capacity and establishment of a collaborative organization driving and supporting sustainable food economy development in Phoenix, Arizona

Table 2: GLOCULL Impacts.

5 CONCLUSION

Despite the differences between the innovations in the seven projects, the ULL has proven to be a useful approach to creating a space of interaction for multiple academic and non-academic actors. In this sense, the seven GLOCULL project ULLs have facilitated new and strengthened existing transdisciplinary

collaborations. Moreover, we expect the project to have initiated long-lasting relationships between stakeholders, municipalities and scientists.

The tools developed in the project draw insights from the seven cases, thus being adaptable to different contexts, scenarios, kind of innovation and group of actors. The tools are not only meant to raise awareness about the FWE nexus and to support decision-making, but they also foster and monitor learning processes.

The project gave insights on how to conduct transdisciplinary research and on how the FWE nexus, and system thinking more generally, can contribute in developing solutions both in an urban context considering local and beyond-local impacts.

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