ADVANCING SUSTAINABILITY THROUGH LIVING LABS: A CASE OF THE WATER HUB, SOUTH AFRICA

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Abstract

Living laboratories are sites or arenas that have the potential to advance sustainability transitions by finding ways to strengthen the capacity of actors and agencies in responding to critical social and environmental challenges. South Africa faces significant challenges in public service delivery, which are obstacles to addressing crucial issues of poverty, social inequality, and environmental justice. The study describes the role of academia and other actors in advancing research and innovation in the Food-Energy-Water-Waste nexus. The Water Hub began as a small, abandoned municipal waste water treatment work and was repurposed in 2017 as a research and innovation centre. Academics involved in managing the site were strategically positioned to guide the development of the Water Hub to transform thinking and practice to contribute to a more just, equitable and sustainable world. Since then, the Water Hub has aimed to create an enabling environment by deliberately encouraging the collaboration of multi-stakeholder groups to find sustainable solutions. Progress in becoming a living lab has been slow and uncertain partly because advancement has depended on research-led projects and a willingness of academics to champion the overall project and site management. The Water Hub site has demonstrated innovative and creative ways of treating polluted water, including recovering and reusing resources. The ongoing challenge resides in facilitating community-based collaboration to address the causal factors of those issues that can be addressed through sustainability transition theory-and-practice pathways explored in the paper.

Keywords: Living labs; academia; sustainability transitions; Water Hub.

Introduction

There is a growing interest in understanding how living laboratories can advance sustainability transitions(Puerari et al. 2018; von Wirth et al. 2019)and contribute to systemic change necessary to address complex social and environmental challenges (Abson et al. 2016).Transitions are understood as large-scale disruptive changes that emerge over time, often through unstructured, nonlinear, and unplanned processes that cause a significant shift from one state of equilibrium to another (Loorbach et al. 2017; von Wirth et al. 2019).Transitions are triggered by different disruptions whose origins remain poorly understood(Kivimaa, 2021).For instance, Köhler et al. (2019) claim that sustainability transitions require significant shifts in socio-technical solutions rather than incremental adjustments and suggest that new socio-technical systems are required to support a sustainable transition (Köhler et al. 2019).

This paper examines the journey in the development of a research, innovation and demonstration site called the Water Hub, which is situated in Franschhoek, approximately 75km east of Cape Town, South Africa. The purpose of this paper is to describe how multiple factors influenced the development of the Water Hub in becoming a living lab through a sequence and combination of

research projects and collaborative partnerships and how the governance of the site is helping to build an enabling environment for stakeholders to contribute to food, energy, water and waste challenges. In the early 1990s, living labs were often described as test-bed sites for research and innovation (Schliwa, 2013; Franz, 2015). Since then, new questions have arisen about how living labs can progressively challenge conventional practice and norms. This has resulted in new research refining the purpose of living labs and forms of governance required to enable sustainability transitions. Recent research work also emphasises how living labs are capable of transforming learning into practice (Loorbach, Frantzeskaki & Avelino, 2017) by bringing stakeholders together to learn and act in addressinglocal challenges (Bylund, Riegler & Wrangsten, 2022). Transition management and the role of living labsare still under-researched, especially in the global South. von Wirth et al. (2019: 254) suggest that even in the North,'…we have only started to understand and operationalise their potential in facilitating urban transitions'. Nevertheless, a common theme in the literature is the vital role of collaboration with users and stakeholders in the effectiveness of living labs(Mbatha & Musango,2022).

South African researchers have reviewed different examples of living labs and found that they were largely characterised by activities that were testing products and designs (Coetzee, du Toit & Herselman, 2012). However, since then, there has been a lack of research publications that have investigated living labs further. This lapse in research is surprising since South Africa faces significant challenges in public service delivery, which is strongly connected to endemic poverty, social inequality, and environmental degradation. It seems pertinent for living labs in South Africa to position themselves to advance thinking and practice in public service delivery and in finding ways to strengthen the capacity of actors and agencies in responding to critical social and environmental challenges. The objectives of this paper are therefore:

1.To identify how the form and purpose of a living labcan position itself to facilitate a sustainable transition set in the context of water scarcity, urban poverty and environmental degradation
2. To address the process of engaging with relevant actors in developing a living lab
3. To investigate the role of enablers in the structure and form of the living lab.

Transition management

Recent studies in sustainability research have focused on observing non-linear and multi-phase shifts that progress from one equilibrium to another (Loorbach, Frantzeskaki& Avelino, 2017) and on an improved understanding of the methods and mechanisms thatare disruptive of norms in a transition process (Hölscher, Wittmayer &Loorbach,2018). A combination of methods, mechanisms, insights and novel viewpoints have the potential to instigate a shift in norms (Köhler et al., 2019) through collaborative learning and co-creation activities that are aimed at long-term transitional change toward a more sustainable state(von Wirth, Frantzeskaki & Loorbach, 2020).

According to Köhler et al. (2019), advances in transitions are identified by several distinct characteristics identified in the sustainability research literature as guiding attributes in the development of living labs. These characteristics listed below were identified in the development of the Water Hub in its journey to becoming a living lab:

- Multi-dimensionality and co-evolution
- Multi-actor process
- Stability and change
- Long-term process

- Open-endedness and uncertainty
- Values, contestation, and disagreement
- Normative directionality (Köhler. et al. 2019: 2).

A transition management cycle framework (Loorbach & Rotmans, 2010: 238) (Figure 1) involves a network of diverse actors that can connect and are supported by experimentation and innovation. Thus, living labs become the experimental arena for exercising transition theory. The cycle is subdivided into four general components, beginning with (a) identifying issues and challenges in context and envisaging the transition and appropriate processes that can be developed; (b) developing a transition agenda and vision for sustainability; (c) creating an enabling environment to engage actors and projects that are experimental and innovative; and (d) iterative monitoring, evaluating, and reflecting on learning processes to understand what systems are broken or need to be broken, and what can be restored or re-structured differently to advance sustainability.

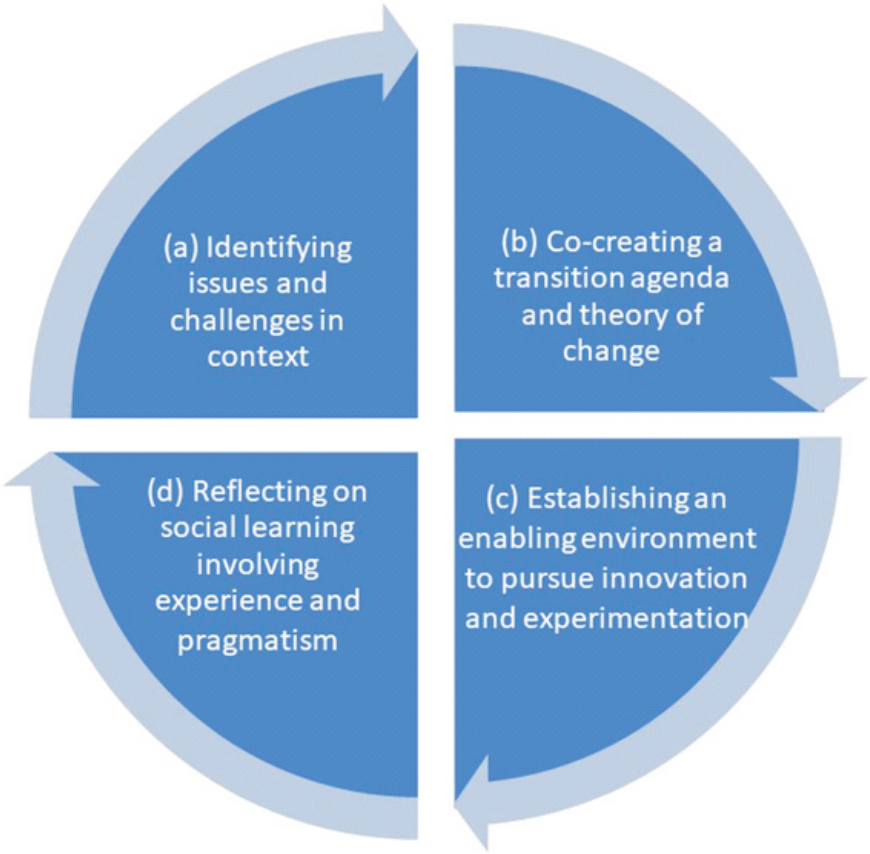

Figure 1: General framework of the transition management cycle (adapted from Loorbach & Rotmans, 2010).

Problem identification and problem-solving are strengthened through effective collaboration, which in turn is reinforced through social learning, building trust, and creatively managing in such a way as to make it easier for actors from different fields to work together (Köhler et al. 2019). Aliving lab provides a site and arena for learning and research, and if successful, contributes to advancing the application of knowledge and can enhance the reputation of collaborators, especially ifthey demonstrate social responsiveness to critical issues in a local or regional context.

Research design

This study builds on the conceptual transition management framework (Loorbach & Rotmans, 2010) by presenting an account of the development of the Water Hub as a living laband its emerging role in initiating transformation and transitions. It describes the role of academia in advancing research and innovation characterised by trans disciplinary research and expanding the scope of projects, such as integrating the Food-Energy-Water nexus and recovering resources from waste. By drawing on scientific findings and the support from research partners involved in the various studies, the living lab has evolved to position itself to offer an open invitation to collaborate in research work that involves the local community, entrepreneurs, academia and interested parties. These advances in the development of the Water Hub are identified in the observations and written material collected at public workshops. One of the workshops was designed to generate a shared vision and action plan for addressing issues in the catchment.

Background to the Water Hub as a living lab

The Water Hub initiative began in 2017 after the local municipality had abandoned a small wastewater treatment works (WWTW). The plant had overreached its capacity, and a new one, situated approximately 5km north of the existing site, was commissioned and operationalised in 2013. The old WWTW presented an ideal opportunity to repurpose the infrastructure to support a range of nature-based solutions (NbS) for treating and reusing contaminated surface water discharging into an adjacent river. The source of contamination is mainly from an informal- and low-cost housing settlement located a mere 1km further upstream of the Water Hub.

The Water Hub's location and context are set in a microcosm that typifies South Africa's socio-economic conditions and reflects the legacy of spatial planning and racial segregation under the Apartheid system. For example, the Group Areas Act of 1950controlled the right to acquire property and the occupation of land based on racial classification. It prevented black South Africans from living in formalised, serviced towns and cities. When the Act was repealed in 1991, and later with the election of the first democratically elected government in 1994, it opened the way for people to move from rural areas and underserviced township settlements to urban areas. Rapid urbanisation resulted in an overwhelming demand for new housing stock; consequently, despite government efforts to provide state-funded housing as part of its Reconstruction and Development Programme (RDP), the short fall in housing led to the growth of informal settlements. By 2018,an estimated3.6 million people lived in informal settlements (SERI, 2018). A brief overview of the origin of informal settlements provides the backdrop to the site and context of the Water Hub. It is representative of conditions currently found on the periphery of many South African cities and towns.

The Water Hub is in the picturesque Franschhoek valley (See Figure 2), where local and international visitors are drawn to enjoy its beauty, viticulture, wine tasting, and high-quality cuisines. By contrast, approximately 7 500 people live in a densely populated informal and low-cost housing settlement, of whom 64 percent live in the informal settlement of Langrug. This settlement comprises over 1 800 households that share 150 communal ablution toilets (Stellenbosch Municipality, 2018) and limited access to water, formal drainage and waste collection services. In the absence of formal sewerage systems, residents have little choice other than to discard their unwanted water from their homes onto the street, into makeshift drainage channels or in resident-installed pipelines from the home that discharge into **nearby shallow** storm water systems. Grey water accounts for most of the discarded household water, which often flows

across the surface into receiving water bodies such as wetlands and streams and can also infiltrate groundwater. This run off usually combines with black water spilling from dysfunctional communal sanitation systems, leaking toilets and sites of open defecation. According to studies in South Africa, runoff from informal settlements contains elevated COD concentrations between 1500 and 8500 mg/L; oil and grease between 30 and 2000 mg/L; electrical conductivity between 50 and 1500 mS/m; and bacteriological colony forming units / 100ml (cfu), which is similar to untreated sewage (Armitage et al. 2009).

Figure 2 shows the location of the Water Hub and its catchment. The perennial Franschhoek and Stiebeuel rivers flow through the Franschhoek valley with their source from the Drakenstein (south-east of the mapped area) and Hawequas Mountains. About 80% of the rainfall falls between April and September, with an average annual rainfall of 784 mm in the lower valley and 903 mm in the upper reaches of the valley (Fell, 2017). The Stiebeuel Rivertraverses through the Water Hub and drains a small area of 4.69 km^2. It flows through loamy sand and clayey soils at an average gradient of 1:12 (Armitage et al. 2009).

The Water Hub was initially conceptualised as a sustainable drainage (SuDs) centre that could treat surface water runoff from the informal settlement. The focus on treatment shifted slightly later to a bioremediation approach using NbS, using natural media and vegetation to treat and potentially remove contaminants carried in the runoff. The catalyst for the project began with a 3-year open tender award designed by the Western Cape government's Department of Environmental Affairs and Development Planning (DEA&DP).The award was made to a small consulting engineering company, which, in turn, invited academics from the Future Water Institute at the University of Cape Town (UCT) to contribute as a partner in the project. A further aim included the development of a conceptual and business model for the site's future development. The tender included a small budget for repurposing some existing infrastructure on the site. Despite conversations with the Western Cape government and the Stellenbosch Municipality and enthusiastic visits by their senior officials, no formal land agreements could be achieved, leaving the responsibility for developing the Water Hub further to academics at UCT.

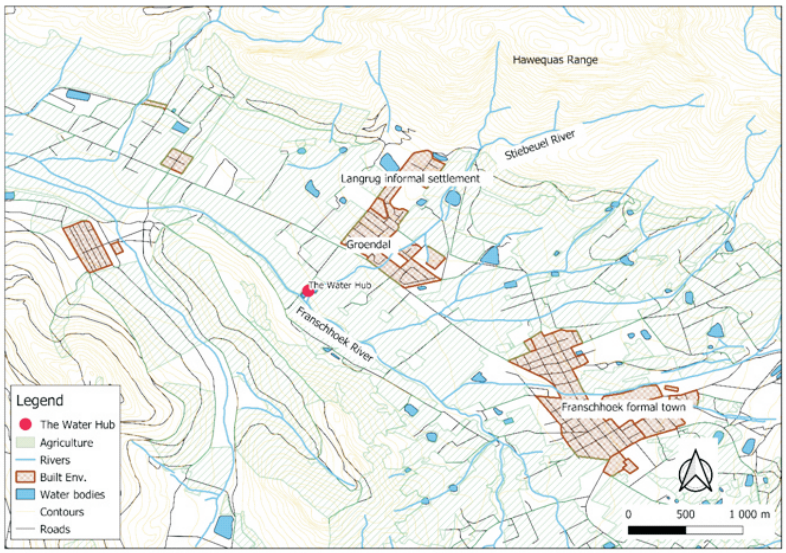

Figure 2: The Stiebeuel River catchment, Groendal and Langrug settlements and the location of the Water Hub (Map created by: Winter, 2023).

In 2017, research work at the Water Hub began after the original drying beds were repurposed to form large-scale biofiltration cells, each of which was packed with natural media comprising stone aggregates of different sizes and peach pips (kernels/stones) and, later, biochar replaced the peach pips after they proved to be less effective in water treatment. Studies were conducted over 3 years to determine the efficiency of removing or degrading nutrients and bacteria. During this time, confidence grew in the management of the treatment processes. Approximately 100 kl of water every 5 – 7 days achieved a water quality standard that complied with South African Water Quality Guidelines (DWAF, 1996) and World Health Organisation guidelines (WHO, 2001) for irrigation and the discharge of treated water to waterways. From 2017 to 2020, the research concentrated on understanding the performance and management of treating water to irrigation water quality standards (Winter et al. 2023). Their findings showed that vegetated and non-vegetated cells effectively reduced NH_3 and PO_4^{3-} concentrations of contaminated water by 85% and 98%, respectively. Vegetables were grown as biomarkers to determine the risk of using NbS-treated water quality for irrigating edible crops.

To progress the sustainability transition, there need to be groups of "enablers" –individuals who engage with the project and its aims, ultimately assisting in driving the transition forward. These enablers include universities, private enterprises, local and provincial government and residents. Without these enablers, the Water Hub would not progress in becoming a living laboratory as highlighted earlier (Loorbach, Frantzeskaki& Avelino, 2017; Bylund, Riegler and Wrangsten, 2022).The following sections outline their roles in the project.

Universities as enablers

Universities have a reputation for being agents of change because of their influence in knowledge production, the development of innovation and thought, and the ability to connect with local stakeholders and global networks. They are well-positioned to transform thinking and practice toward a more just, equitable and sustainable world. It is not surprising, therefore, that university-led living labs have the potential to collaborate with multi-stakeholder individuals and groups in fostering local innovation and community-based projects. In addition, there are new interests in research and funding opportunities that enhance trans-disciplinary approaches in teaching and research, which also contributes to improving the university's reputation and in responding to societal issues (Purcell, Henriksen & Spengler, 2019) and in keeping sustainability at the centre of its approach. The university-led development of the Water Hub is firmly focused on NbSto address societal challenges, which include reducing livelihood risks and exposure to pollution, improving local environmental conditions and supporting the restoration of ecological systems and services. In the early development stages of the Water Hub, the research focused on treating water. Still, at this stage, there was no attempt to encourage local residents to become involved in the site while the treatment system was still being trialed. Two years of data collection and analysis were necessary before there was sufficient confidence in the efficacy of the treatment and before an invitation could be extended to others to participate in the venture. With growing confidence, the project set about bridging the gap between authorities, local residents and other interested stakeholders by creating an open invitation to contribute. Academics who understood the importance of collaboration committed themselves to developing the Water Hub this way and kept looking for new opportunities to attract new research projects. Significant international partnerships arose from projects such as the Royal Society research project focused on bioremediation in treating contaminated water from an informal settlement and the Sustainable Urbanization Global Initiative Belmont Forum Waste FEWULL project

(https://wastefewull.weebly.com/) centred on the food-energy-water (FEW) nexus became catalysts to bring attention onto resource recovery and reuse.

The Royal Society project helped to secure a partnership between the University of Cape Town and Coventry University and a collaboration between two experienced academic colleagues in the use of NbS treatment of contaminated water and the use of SuDS to manage runoff from informal settlements and refugee camps (Charles worth, Mc Tough &Adam-Bradford,2019). The grant helped advance investigations into the safe reuse of treated water for irrigating experimental gardens at the Water Hub and set about involving local residents in growing and managing food gardens. This included a small group of gardeners who were given basic training and offered a small stipend to grow the vegetables. They were encouraged to explore potential market outlets once the crops were harvested. From each harvest, the crops were tested at an accredited laboratory (BEMLAB Pty (Ltd)) that specialised in analysing agricultural produce and soils to provide some quality assurance that the crops were fit for human consumption. However, the growers showed little interest in marketing the vegetables or making a profit from their sales. Instead, the vegetables were donated to a local soup kitchen.

In 2018, the Waste FEW ULL project brought together an international consortium from four different countries in a study to identify inefficiencies in waste production in an urban FEW nexus. This project significantly adjusted the scope of work at the Water Hubby demanding greater flexibility and an adaptive approach that went beyond the initial focus on water alone. In addition, with increasing success in using NbS for treating water, it was logical for the development of the living lab concept to be tested further by going beyond the site's boundary. In keeping with principles of recovery and reuse, food gardens were prepared from recycled green waste obtained from a municipal landfill site. A series of raised garden beds were planted using an approach that broadly subscribed to perma culture principles and used companion-based planting techniques. With growing confidence and assurances of the risk of using treated water, consultations were started with an acknowledged Langrug Community Forum (LCF) community leader. These discussions resulted in the temporary employment of three young female students, all in their final year of agricultural science studies and living in the informal settlement. They successfully produced a range of vegetables but felt they needed more confidence in finding a marketplace once the crops were harvested.

Integrating waste efficiencies and recovery in the Waste FEW ULL project resulted in a further scientific study on green waste and soil improvement in the Soil Nexus project funded by Future Earth. This project focused on the potential and risk of reusing recycled green waste in regenerating soil, involving university and non-government partners from the global North and South. It featured the Water Hub and a second case study in Rosario, Argentina. This project was primarily responsible for developing a controlled experimental garden comparing crops treated with water from the municipal supply and those treated on-site from the biofiltration cells. Control beds were compared with various interventions, including composting the soil with duckweed and inoculated biochar that increased soil carbon content, infiltration rate and moisture retention. Four successive harvests showed a slight increase in mineral uptake of K, Fe and Mg in plants irrigated with the combined effect of biofiltered water and a mix of inoculated biochar.

These three projects significantly contributed to expanding the research activities in a practical demonstration, giving new insights into NbS, including soil regeneration and food security. They also reflect what ENoLL (European Network of Living Labs) defines a living lab as, real-life test and experimentation environments that foster co-creation and open innovation", with a focus on integrating research and innovation processes in real community settings (Filho et al., 2023), and

further contributes toward this research project's aim of exploring how the greater LL concept and its potential for application in various Global South contexts can enable sustainable transitions. However, the experiment remained assuch and offered only a limited scope beyond the site's boundaries. The researchers understood that collaboration with local stakeholders must be included in advancing a test bed site to become a living lab.

A further initiative and partnership arose from the African Research Universities Alliance (ARUA), a collaboration of seven other African universities with the Water Centre of Excellence (CoE) located at Rhodes University, South Africa. The project entitled, 'Unlocking resilient benefits from African water resources' (RESBEN), aimed at realising the Africa Water Vision 2025 through an Adaptive Systemic Approach (ASA) framework (Palmer et al. 2023). The approach was characterised by transformative, trans-disciplinary, and community engagement in research that aimed to shift water development outcomes by bringing attention to access and availability of water supply and water quality. Each participating university was tasked with developing a research agenda that would strengthen the capacity of local stakeholders in a participatory governance approach for equitable water sharing, community resilience in managing polluted waters and ecosystem protection and restoration. The ASA framework included co-creating a vision for the respective catchments at each site within the consortiums and plans for acting. This project represented the first significant effort by the Water Hub to engage with a broader range of stakeholders interested in addressing pollution issues in the Stiebeuel River catchment. Two workshops were held with local residents, non-governmental organisations, civil society, educators, private enterprises, and water managers from local and provincial governments. The 'local community as enablers' section discusses the workshop's outcome.

Table 1: Significant research projects in the development of the Water Hub

Project Title: funder and partners	**Period**	**Aim**	**Summary of outcome**
Royal Society: Determining the performance of large biofiltration cells in treating contaminated runoff from a slum settlement and its reuse for urban food production	2019 – 2023	The study of large-scale biofilters aims to understand the media's optimal performance without adding chemicals in the treatment process.	Surface water flowing downstream from the informal settlement collects contaminants such as personal care products, pharmaceuticals and waste before entering the main river.Biofilter effluent showed a remarkable reduction in contamination; water quality now meetsgeneral standards for aquatic systems and for irrigating edible crops. Analysis of harvests of leafy and bulbous vegetables irrigated using the effluent indicates that they are suitable for human consumption, with a reduction in nutrients and *E. coli*.

Waste FEW ULL: Waste Food-Energy-Water Urban Living Lab - Mapping and Reducing Waste in the Food-Energy-Water Nexus European JPI	2019 – 2022	To develop and test internationally applicable methods of identifying inefficiencies in a city-region's food-energy-water nexus.	he Waste FEW ULL project focusesnot on the specific downstream challenges but on upstream processes by which cities can identify, test and scale viable and feasible solutions that reduce the most pressing inefficiencies in each context.
Soil Nexus Future Earth Spark Funding Initiative: Integrating science for sustainability	2020 - 2022	Building policy tools for water and waste-based urban soil remediation	Creation of 2 x 12m garden corridors comprising control plots, a biochar inoculated plot and a duckweed compost plot. Each garden corridor is irrigated either with treated municipal or biofiltered water. Five harvests of vegetables showed that biofiltered irrigation water and biochar (increasing in carbon)tended to improve crop water retention and mass, including a slight increase in minerals (Fe, Mg and K) acceptable within norms and no significant soil impact.
ARUA RESBEN: UKRI	2018 – 2023	Novel research theory, methodologies and practice to meet the UN SDGs and to realize the Africa Water Vision 2025.	To apply transformative, trans-disciplinary, community-engaged research to shift water development outcomes towards achieving the SDGs. Address water development priorities of supply and pollution. Significant support and value were placed on the ASA approach to community engagement in information-sharing workshops, the development of an agreed-upon catchment vision, and some progress in executing tasks to address waste and government support to restore sections of the affected river.

Private enterprise enablers

An open invitation to entrepreneurs and businesses raised new interests and questions and the potential of forming new partnerships. Since 2022, three small companies have tested various water treatment products and techniques: (a) a low-dosage copper-sulphate solution for removing blue-green algae from lakes; (b) biochar used as a water filtration media; and (c) testing new techniques in clearing a degraded river and restoring the banks with riverine vegetation. Researchers at the Water Hub supported these entrepreneurs by assisting in the research design and conducting systematic testing and analysis. To date, no formal agreements or costs were demanded from these businesses partly to encourage an increasing openness to participate and share new ideas and questions but also on the assumption that innovators will reciprocate in some way by offering further support for the development of the living lab. The involvements of three private enterprises is listed in Table 2.In summary, entrepreneurs are enablers who bring expertise and experience to the living laboratory. In some cases, they raise new or different questions, extend the activities by introducing new experimental designs and methods and advance post-graduate research experience by adding another dimension to their research, often by loaning laboratory equipment and other machinery that extends their research experience.

Table 2: Business enterprises and initiatives investing in the development of the Water Hub

Project Title: funder and partners	**Period**	**Aim**	**Summary of outcome**
Global Earth Science Laboratories	2023	To test the application of a low dosage of hydrogen sulphate to remove microcyst in algae from a small concrete dam previously used as the primary settling pond on the site.	Samples were collected each day for 10 days and monitored for changes in pH and chlorophyll a. Algae was reduced by 80%. Cooler temperature conditions and rainfall removed the remaining concentration of algae within two weeks after monitoring was completed.
Financial support from SA's Independent Development Corporation (IDC) in a grant to Crislor Environmental	2022- 2024	To test new forms of nature-based processes to improve the quality of surface water discharge into rivers and waterways	The establishment of a small laboratory to test different configurations of treatment trains, the production of biochar from non-indigenous vegetation, investment in experiments to dewater an abandoned maturation pond at the Water Hub, and the safe reuse of sludge as a building material insulator are all ongoing. Experimental infrastructure and data collection are in place.

Financial support from the Western Cape government in a tender awarded to Intaba contractors.	2023 – 2024	Rehabilitate the banks of the Stiebeuel River using indigenous plant species as pollution phytoremediation corridors. Design and assemble a removable litter trap to capture, remove, and monitor solid waste emanating from the catchment.	The project aligns with the community vision for the catchment, which focuses on solid waste management and disposal in the river. Preparing riverbanks involves glyphosate herbicide sprays, controlled burning, and a drip irrigation system designed to operate at 1.5 bars using only renewable energy to achieve optimal pressure and pumping.

Local and provincial government enablers

In the global South, there are limited examples of local municipalities with the capacity and resources to support experimentation in developing social technologies for enhancing public servicesEvans,Karvonen&Raven,2016).Understandably, as noted by Mukhtar-Landgren, et. al (2019), municipalities are often unable to invest in research-led initiatives because their attention and resources are spent on other immediate priorities and challenges. Municipalities in South Africa are often overwhelmed by a plethora of demands and are likely to resist change potentially disruptive to existing organisational structures. In these circumstances, it is difficult even for relatively well-resourced municipalities to be involved as active partners in developing a sustainability transition agenda. However, living labs that have a close partnership with research institutions can offer a convenient bridge for authorities to collaborate with research institutions without taking direct responsibility for the research and daily management of the site. When the Water Hub project started, the local municipality granted the use of the siterent-free with the only proviso that no permanent structures could be erected. Still, it offered no agreement to collaborate or make any demands on the researchers or their research activities.

As mentioned earlier, the Western Cape provincial government played a significant role in establishing the Water Hub research site by providing an initial investment through the public tender in 2017. The award was made to a small engineering company, Isidima. This award enabled the contractor to repurpose some of the infrastructure, such as the drying beds, as described earlier, into large biofiltration cells and to rebuild the site manager's accommodation and storeroom facility. However, as typically occurs, once the project tender is complete, the researchers are left to continue the project. However, communication has been maintained with officials from the Western Cape Provincial government's DEA&DP. The Provincial government continued to invest in the Water Hub in 2023byawarding a new contract to rehabilitate a section of the Stiebeuel River (Table 2). In addition, it was instrumental in facilitating a research partnership between UCT and the Technical University of Munich, which is engaging in a project at the Water Hub, which the German Federal Ministry of Education and Research funds. This partnership aims to advance the integration of the FEW nexus by examining nature-based technologies and expanding the scope of current activities at the Water Hub. The study will include support for business entrepreneurs' development knowledge dissemination and capacity building of project partners and stakeholders.

Local community as enablers

'User-driven' initiatives (Lupp et al. 2020) have interests in advancing ideas and are also potential beneficiaries through co-creating solutions and actions. They include civic activists and actors, NGOs, and community-based organizations who contribute from the 'ground up'. Their participation in the living labarena is characterised by varying levels of involvement and different stages in the development of the laboratory that can extend from the initial planning through to co-design, implementation, and evaluation (Lupp et al. 2020).

In 2022, two workshops, briefly mentioned earlier, were organised at the Water Hub and attended well by municipal officials, elected councilors, residents, NGOs, and researchers. The first workshop involved sharing information and data about the work at the Water Hub, and the second followed a format used in the RESBEN project adaptive planning process (APP) framework described earlier. One outcome of the latter was drafting a collective vision and set of tasks to address the degraded condition of the Stiebeuel River catchment (29 September 2022). Key issues and concerns were also recorded, which included a list that highlighted the frustrations that residents expressed in their experience of living next to a degraded and polluted river. A total of 43 participants were present during the day-long workshop and represented the interests of schools, churches, clinics, community groups, ratepayers, business chambers, private business owners, local and provincial government, NGOs, and researchers. During the workshop, participants were asked to write short sentences about their knowledge and experience of the Stiebeuel River. Accounts were recorded verbatim, highlighting their general concern about the dumping of solid waste and sewage, the state of poor public sanitation service and the safety concerns of the children who play in the river.

The participants were taken on a walking tour of a section of the river, which highlighted further concerns which were captured in the following statements:

> "Copper burning and selling waste materials has become a way of earning money for many community members. This is done next to the river. People also dump the waste from bins into the river and sell these bins for R5 to the spaza shops".

> "I grew up next to the river when it was still an apple orchard. These orchards were then replaced with housing developments. The settlement has expanded so quickly. Now people are living very close to the river. The shape and flow of the river have also changed dramatically over the years. It is much narrower and the flow is obstructed by large waste materials (e.g. mattresses, televisions)".

Participants agreed on a broad vision for the Stiebeuel River catchment and reached a collective agreement, which was expressed as follows:

> "A clean and safe Stiebeuel River catchment with a well-informed community, supported by strong governance, striving for social justice, environmental restoration and preservation, for the benefit of all".

Consideration was given to accomplishing this vision, and the importance of encouraging local participation and building well-informed communities was emphasised. As such, the Water Hub

was identified on several occasions as a site that offers the opportunity to become increasingly well-informed and increase participation in some of the practical solutions to encourage initiatives and or incentives, thus shifting the perception of solid waste to the perception of a resource, to reignite hope in communities, as well as raising the crucial point of supported and fair governance as a reminder that "governance" represents both government and people. There was an overwhelming concern for the condition of the river and the dumping of solid waste along its banks. The perception of waste as a spent resource was also raised in the discussion on actions that require behaviour and attitude change. One municipal official suggested that river rehabilitation and floating litter boom projects should involve the community and engage youth in restoration programmes. This suggestion was taken up by a provincial government official who attended the meeting and resulted in a public tender that was advertised by the Western Cape government and was awarded to a small consulting company (Table 2). By 2023, the rehabilitation of a 250m stretch of river at the Water Hub had begun. More discussion was needed among the participants about the underlying reasons for the degraded state of the river, for example, the lack of waste management and sanitation services that directly impacted the river's condition.

Discussion

The development of the Water Hub grew organically but always tried to focus attention on the causal effects of water pollution. The daily experience of people living in the informal settlement was poor access to water, sanitation, and waste services and concern that the socio-economic circumstances of the residents were holding them in a poverty trap. These grand challenges dominate the small catchment area and will require significant intervention to change the status quo. It will require a significant disruption to shift these circumstances toward a sustainability transition.

As described earlier, the initial concept of the Water Hub began with abandoned wastewater treatment works and its re-purposing for research in developing SuDS technologies for treating surface water runoff from an informal settlement. After two years of water quality data collection and analysis, the results showed that the treated water could irrigate vegetables. However, at this stage, there needed to be more evidence that the Water Hub contributed to improving the local environment or engaging with stakeholders and residents in the informal settlement. It became increasingly apparent that if the Water Hub were to progress in forging a transition, it would have to look 'beyond the factory fence' and recognise the value of multi-actor engagement in co-creating the living lab. As the work advanced, increasing numbers of local and international visitors, mainly from the education and research sectors, were attracted to the site. These visitors could not always see or even imagine how the project could be up scaled and were often not inspired by NbS water treatment alone. They raised questions and concerns about the shape and form of the Water Hub and identified the need to encourage a diversity of project initiatives. Some questions were always asked about how the projects could involve local residents. The early stage in the site's development was relatively easy because the work focused on research activities but made little progress in addressing the grand challenges of urban poverty, unemployment and an under-resourced, degraded environment in the settlement. The development of the Water Hub as a living lab cannot be immune to these circumstances, but its resources were limited to research-funded projects.

The journey towards a sustainability transition and progress in developing the living lab will likely take time. The acceleration of these processes remains dependent mainly on academics and researchers in taking the lead and finding the necessary resources to fund the site, innovation, and development. The open invitation to participate in the development of the facility attracts

entrepreneurs who wish to test ideas and products and encourages site visits and information sharing amongst local residents and authorities. These are the means to start the conversation and consider the challenge. Transitions are more likely to begin following an iteration of reflexive learning in a pragmatic approach to 'learning by doing'. The expectation is that a multi-actor involvement will generate new and unanticipated pathways in finding creative ways that nudge and accelerate change. The journey of the Water Hub holds the promise of further progress but is tainted with an uneasy mix of paralysis, uncertainty, risk, and an uncomfortable tendency to resist change (Figure 3). These tensions need to be managed. Pathways in the development of the living lab are far from predictable and usually non-linear(Köhler et al. 2019). However, the value of the Water Hubis that it provides a significant centre of leadership and a platform for recognising and responding to the harsh realities that confront local residents and environmental conditions that are legacies of the Apartheid system and scenarios restraining urban development in South Africa. Moreover, the site attracts visitors who explore knowledge and contribute new ideas and inspiration. On-site visits, for instance, have enabled participants to gain increased knowledge and experience in NbS to address complex challenges.

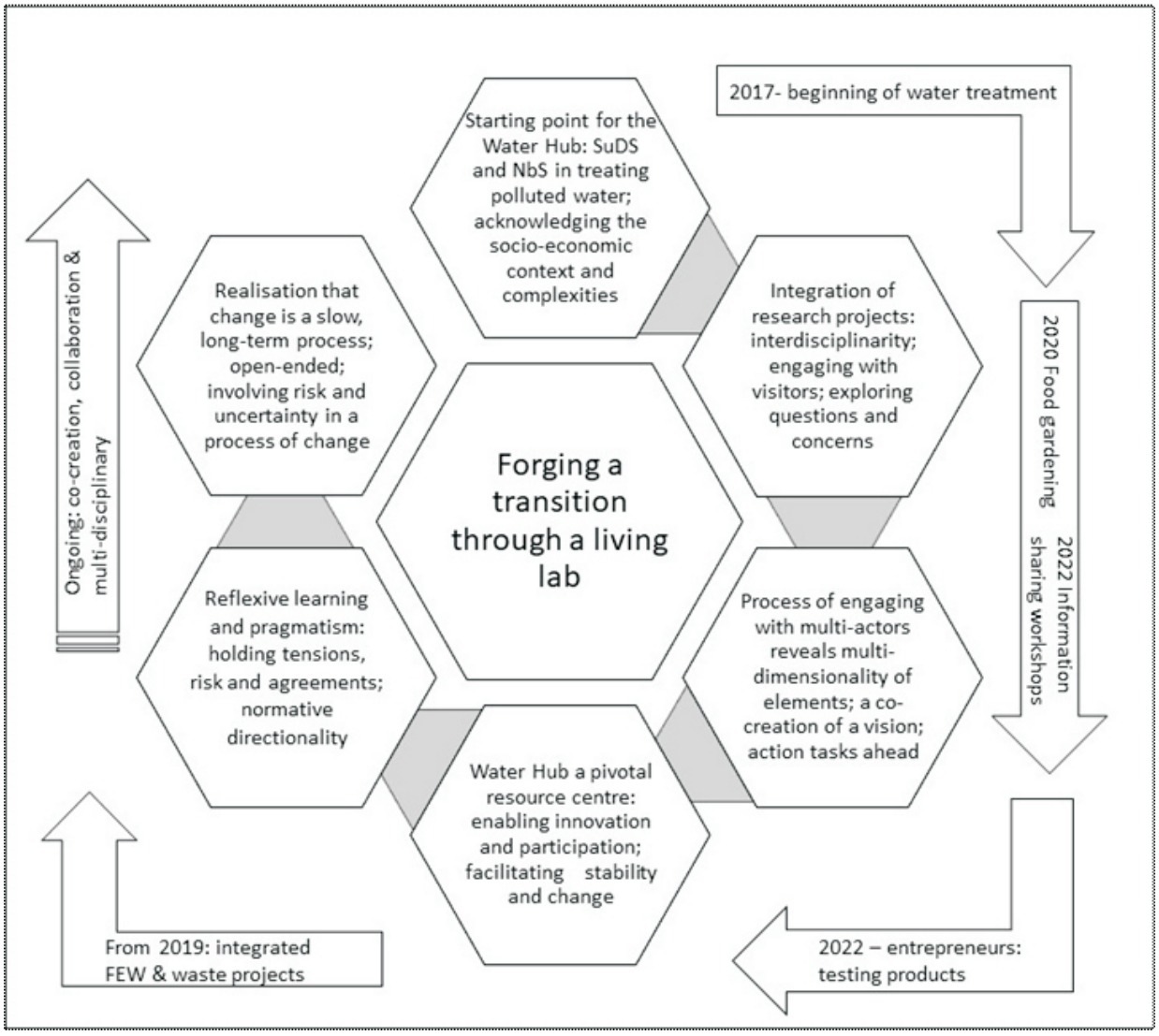

Figure 3: Pathways and elements of sustainability transitions and a living lab at the Water Hub

Conclusions

The journey of the Water Hub from its previous state of an abandoned wastewater treatment plant to a research and demonstration centre is attempting to follow an acknowledged pathway toward a sustainability transition as suggested by researchers such as Köhler et al. (2019) and von Wirth, Frantzeskaki & Loorbach (2020). Following the initial start in demonstrating how NbS treated contaminated water, the academics soon recognised the importance of creating an enabling environment and extending the reach of the Water Hub by turning attention to socio-ecological issues and concerns in the catchment. An open invitation to visitors to attend a site walk about and to engage in conversations about the work in finding innovative and creative ways of dealing with multi-dimensional challenges on the site and in the surrounding context. These conversations often confirmed vital interests in NbS at the Water Hub. Still, they also raised concerns about the limitations of the project and the lack of integration of issues such as food, energy, waste, health, inequalities, and social justice. It became apparent that if the Water Hub became acknowledged as a living lab and a significant player in affecting change, it needed to take steps to 'go beyond the factory fence'. Research project awards such as the Royal Society, Waste FEW ULL and the Arua RESBEN included opportunities for co-creation and co-evolutionary approaches that enlisted a collective effort to consider the FEW nexus and waste challenges through workshops, community engagement with the experimental food gardens and an invitation to entrepreneurs to experiment with new ideas and products. Living labs are best characterised by an open invitation to co-create knowledge and facilitate learning in which all contributors are valued and respected. In the specific case of the Water Hub, this entails engaging with people impacted by their living conditions, which is located at the centre of activities in conversations, information collection, and collaborative actions (Lupp et al. 2020).Co-creation and community experimentation are key components of living labs and significant parts of transformation and transition research (von Wirth, Frantzeskaki and Loorbach, 2020).The transition from solution-centred experiments to a challenge-driven approach is slowly changing the governance of the Water Hub as opportunities arise. The challenge of addressing a whole catchment and the causal effect of pollution is overwhelming and cannot be achieved by the Water Hub or academia alone. The potential is in creating an enabling environment that aims to integrate the governance of the catchment with like-minded individuals, including representatives from the authorities, businesses, NGOs, and local residents, in finding ways to support a sustainable transition. The living lab at the Water Hub is making some progress toward new thinking and practice that has the potential to affect such a transition despite concerns that progress is likely to be too slow, long-term, and uncertain. For South Africa, finding alternate ways and disruptive means of addressing wicked problems to overcome entrenched social inequality and poverty will be increasingly important.

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