Impacts of real-world labs in sustainability transformations

Forms of impacts, creation strategies, challenges, and methodological advances

Real-world labs are witnessing continued growth and institutionalization in the field of transformation-oriented sustainability research, as well as in adjacent disciplines. With their experimental research agendas, these labs aim at sustainability transformations, however, there is still a need to improve the understanding of their impacts. Drawing from this Special Issue's contributions, we offer a broad overview of the impacts achieved by various real-world labs, highlight the diverse areas and forms of impact, and elucidate strategies as well as mechanisms for achieving impact. We present methodological advances, and address common challenges along with potential solutions for understanding and realizing impact.

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Understanding impacts of real-world laboratories

Real-world laboratories (RwLs) and related experimental approaches are high on the agenda, gaining traction in research and on funding agendas, and attracting political and public interest (McCrory et al. 2020). Numerous projects labeled RwL cover diverse topical areas, particularly in the German-speaking context. The concept of RwLs is deeply rooted in transformative sustainability research, with the ambition of achieving a Great Transformation (WBGU 2011) of our societal structures, lifestyles and economies: a profound systemic shift towards a future-oriented and sustainable society.

RwLs are characterized by their transdisciplinary and action-oriented nature. They provide an environment for co-creative, participatory experimentation and learning aimed at understanding, supporting, and accelerating fundamental change towards sustainability (Parodi et al. 2023, Schäpke et al. 2018b, Caniglia et al. 2017, Wagner and Grunwald 2019, Schneidewind et al. 2016, Bergmann et al. 2021). Since their first introduction in 2012, RwLs have been the subject of productive discussions regarding the mode of research, infrastructure, their similarities and differences to other transdisciplinary and transformative approaches, and their methodological implementation (e.g., Schäpke et al. 2018a, Defila and Di Giulio 2018, Beecroft and Parodi 2016). RwLs are part of a broader trend of social experimentation within specialized labs, with adjacent approaches such as Urban Living Labs, Urban Transition Labs, Transformation Labs and Challenge Labs (see McCrory 2020 for an overview).

The recent growth of RwLs – in terms of broad application and political uptake – underscores the importance of under-

standing their actual impacts and impact mechanisms. This is especially true, as RwLs are also applied in high risk and high uncertainty areas of technological innovation, such as artificial intelligence, critical medical services, or autonomous driving, with calls for further expansion (BMWi 2019). Sustainability issues are thereby not always the primary goal (Wagner and Grunwald 2019). Growing prevalence comes with a growing responsibility.

Most recently, and in order to establish standardized, innovation-friendly framework conditions for RwLs, the German Federal Ministry for Economic Affairs and Climate Action is drafting a *Real-world Laboratory Act,* pending federal government approval (BMWK 2023). The Network Real-world Labs for Sustainability (box 1) emphasizes the necessity for this legislative framework to reflect RwLs' commitment to sustainability, transformation and societal learning as well as good practice of transdisciplinary research (Parodi et al. 2023).

Despite the expectations of a strong transformative potential of RwLs, the actual relevance of RwLs and their impacts on transformation require further empirical and theoretical exploration. The challenge of identifying, analyzing and assessing the impacts of transdisciplinary and transformative research lies in its inherent complexity (Belcher and Halliwell 2021). For example, the possibility to plan for the impacts of RwLs remains limited, as unintended consequences as well as continuous iteration and adaptation of RwL processes are common. The ability to retrospectively reconstruct causal chains remains restricted. A further complication to understand impacts arises from the simultaneous use of methods and processes to generate real-world impacts as well as research data (Augenstein et al. 2022). Therefore, structured and comprehensive attempts to deepen the understanding of impacts are essential, which are the impetus for this Special Issue.

We begin by situating this Special Issue within the context of its origins, followed by an outline of critical areas for advancing RwL research, practice and impact. We then present the contributions to this Special Issue organized around these critical areas, before concluding with key insights and directions for future work.

Contextualization of the Special Issue: Real-world laboratory network and conferences

This edition is based on the work in the Network Real-world Labs for Sustainability. It was inspired by the network's first biennial conference[1] in June 2022 in Karlsruhe. The conference attracted 300 participants from research, policy and practice and 115 contributions were presented. They demonstrated the diversity of projects and the emergence of a vibrant, transdisciplinary community (Wagner et al. 2022). The interest in RwLs as a form of transdisciplinary and transformative research was clearly grow-

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BOX 1: Network Real-world Labs for Sustainability

The network was founded in 2019 and comprises 50 organizations and over 80 active and completed RwLs mostly in German-speaking countries. Many of the members have been working more than ten years in the field of RwL research. They have significantly shaped the theoretical discourse and realization of RwLs and contributed to their promotion. Contributing to sustainable development is particularly important to the network.

Mission: The network is a hub for information, communication and cooperation. The RwLs represented by it develop knowledge for a sustainable development and initiate and support transition processes: in RwLs, research and practice go hand in hand for a more sustainable future. In this sense, the network considers itself a part of a transformative research landscape. Membership is open to individuals, projects and organizations.

Objectives: The network aims for and acts to:
- contribute to the dissemination and strengthening of the idea and practice of RwLs for sustainability;
- serve as a point of contact for people who are interested in RwLs and transformation;
- share information and knowledge (e. g., via the website, news, blog, and mailinglist);
- foster cooperation, connect members and support their work,
- host joint events (e. g., biennial conferences), realize joint publications;
- foster transformative sustainability research and science for sustainability;
- support and connect local authorities, projects, initiatives, groups and people who are (cooperatively) heading towards a sustainable future.

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ing. However, the conference also highlighted the need for a thorough and encompassing discussion on impacts, including the monitoring of impacts, their assessment, and the possibilities of planning impacts. In response, the conference organizers from the Karlsruhe Transformation Center for Sustainability and Cultural Change at the Karlsruhe Institute of Technology together with the coordination team of the network issued a Call for Contributions for this dedicated Special Issue on RwLs and their impacts (GAIA 2023).

Critical areas for understanding and advancing real-world laboratory impacts

One of the challenges as guest editors is to identify the overarching themes that link the various individual contributions to the broader debate. Building on the Call for Papers (GAIA 2023), we identify at least four critical areas and associated questions vital for understanding and advancing impact in and through RwLs:

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Forms and types of impacts generated:
What counts as impact and to whom?

The forms and types of impacts targeted by an RwL encompass not only physical changes, such as technical innovations, but also social changes. These include the creation of new actor groups, changes in governance or regulatory frameworks, and advancements in learning and capacity building (Luederitz et al. 2017). The generation of new knowledge that is socially robust and action-oriented is another RwL impact. The assessment of impacts is inherently contextual, shaped by political considerations and subject to ambiguity, so that what is claimed to be an impact depends on various actors, their interests, power dynamics and the context. Identifying impacts along certain categories provides some structure for assessment, but it remains important to reflect the social processes that influence these categorizations.

Supportive processes and conditions of impact creation:
How is impact generated?

Given the fundamental goal of societal transformation, understanding the mechanisms of impact generation is crucial. Classical attempts view impacts as the culmination of a series of interactions, ranging from initial inputs through processes to eventual impacts. Recognizing that impacts are co-created, co-evaluated and difficult to plan in linear terms, related scholarship has focused on broader patterns and conditions that facilitate impact realization. This includes strategies for impact, systemic interventions, and identifying success factors (Bergmann et al. 2021, von Wirth et al. 2019). Methodological recommendations for designing labs to create conditions conducive to societal change, as well as Theories of Change and impact pathways, are part of these efforts.

Challenges in researching and advancing impact:
What is difficult and how to solve it?

As a methodological innovation with a hybrid aim of understanding and accelerating change, RwLs are susceptible to various challenges. A deeper and more structured understanding of characteristic challenges can catalyze the development of targeted solution strategies. Several challenges have been highlighted, such as the role of structural conditions of RwLs (Schneidewind et al. 2018) and the ambiguous, politically charged and sometimes conflicting nature of impacts in transformation processes. The diversity and methodological complexity of labs poses challenges to comparing RwLs or sharing solutions among them. Other challenges include scaling up, transferring and generalizing lessons learned from real-world experiments in their specific contexts.

Methodologies for systematic analysis of impact:
How to improve impact research?

The empirical and comparative evaluation of RwL impacts is relatively underexplored. Like other forms of transdisciplinary research, assessing RwL impacts is notoriously difficult for various reasons (Belcher and Halliwell 2021). There is a continuing need for methodologies and measures that improve rigor, depth, comparability, and cross-case learning – essentially enabling a systematic analysis of impacts. Relevant contributions might include approaches to attributing causalities, including quantitative assessments, to interpreting impacts, and to facilitating learning across different contexts. They also include the further development of assessment frameworks and of systematic and formative reflection procedures.

Topics and contributions in this issue

This Special Issue features 15 individual contributions, providing a robust empirical foundation and offering both aggregated and long-term insights, as well as comparative and in-depth perspectives on RwLs and their impacts. These include papers synthesizing experiences from *multiple cases* (Kreß-Ludwig et al. 2024, Erisman et al. 2024, Bauknecht and Kubeczco 2024, Korzhenevych 2024, all in this issue), *comparative case studies* (Guittard et al. 2024, Jung and Wentland 2024, Mitchell et al. 2024, Wiefek et al. 2024 as well as Schäpke et al. 2024, all in this issue), *longitudinal studies* spanning several years of an RwL (Bernert et al. 2024, Noll et al. 2024, Wanner et al. 2024, Christ et al. 2024, all in this issue) and *in-depth case studies* (Franck et al. 2024, Klaever et al. 2024, both in this issue).

The contributions cover RwLs in diverse topical areas: *energy system transitions* (Bauknecht et al. 2024, Schäpke et al. 2024, both in this issue); *sustainability in socio-ecological systems* including biodiversity (Wiefek et al. 2024, in this issue), agri-food systems (Erisman et al. 2024, in this issue), islands (Noll et al. 2024, in this issue) and coastal-rural territories (Guittard et al. 2024, in this issue). Topics also extend to local or urban *mobility transitions and services* (Klaever et al. 2024, Jung and Wentland 2024, Wiefek et al. 2024, all in this issue); participatory and local *climate change adaptation* (Mitchell et al. 2024, in this issue); *sustainable urban/neighborhood development* (Bernert et al. 2024, Kreß-Ludwig et al. 2024, Schäpke et al. 2024, Wanner et al. 2024, all in this issue), and *social development, innovation and education* (Franck et al. 2024, Erisman et al. 2024, both in this issue). While many of the topics are typical for RwLs (e.g., mobility, energy, or urban development), the cluster on socio-ecological systems transformation in particular marks a thematic expansion of RwL work. In the following, we present the individual contributions, including their overall scope and contribution to RwL research and practice.

Forms and types of impacts

Kreß-Ludwig et al. (2024, in this issue, pp. 10–17) synthesize insights on societal impacts of RwLs from accompanying research to 48 projects of transdisciplinary urban research. The study offers a categorization of societal impacts in three impact dimensions of societal and individual changes, governance changes, and physical changes, and corresponding impact fields and impact forms. The authors propose generic pathways for creating

societal impact, as varying combinations of learning and networking, behavioral and physical change, and participation and governance. Key principles on how to promote impacts are derived.

Bernert et al. (2024, in this issue, pp. 18–25) build on a long term urban RwL *Zukunftsstadt Lüneburg*. They focus on broader impacts of the RwL, going beyond the established focus on impacts from experiments. They introduce analytical categories for identifying such emergent impacts: transformative learning, novel governance structures and the lab's role as a boundary actor for sustainability. The framework is used to uncover the emergent impacts of the case, reconstructing the lab design to achieve impacts, and providing evidence of the impacts achieved.

Christ et al. (2024, in this issue, pp. 26–34) evaluate the RwL *Hafen-Ost* in Flensburg (Germany) with an emphasis on its impact on sufficiency in the redevelopment planning and governance process of the former harbor area. Utilizing an established experiment evaluation scheme (Luederitz et al. 2017), the authors discuss the RwL's contributions in promoting sufficiency in governance and planning, and the limitations imposed by dominant economic schemes. They make suggestions for refining the evaluation scheme to better learn from barriers to RwL practice.

Noll et al. (2024, in this issue, pp. 35–43) build on socio-metabolic, transdisciplinary research on the socioecological system of a small island (Samothraki, Greece). The research project, which has been in place for 15 years, is discussed as providing ideal conditions for RwL research. The paper highlights impacts in terms of new institutions, organizations, and socioecological changes, as well as fundamental changes in trust, mindsets, and networks that drive transformation.

Mechanisms and conditions benefiting impact creation
Bauknecht and Kubeczko (2024, in this issue, pp. 44–50) integrate three different strands of recent debates and agendas on sustainability transformation, namely RwLs, regulatory experiments, and sandboxes. The authors propose a typology of regulatory experiments as policy instruments and explore options for combining regulatory experiments and RwLs. In particular, the authors discuss directionality and scaling as key contributions of regulatory experiments to sustainability transformations.

Mitchell et al. (2024, in this issue, pp. 51–56) elaborate on the role of social cohesion in real-world experimentation and scaling of impact, using the urban RwL *GoingVis* as a case study. The authors identify social cohesion as both a prerequisite and an outcome of RwL research, anchoring the RwL in the social dynamics of the respective field. They then discuss the importance of considering social cohesion in the temporal and spatial scaling of real-world experimentation impacts.

Guittard et al. (2024, in this issue, pp. 57–63) share findings from research conducted in three European coastal-rural regions – Spain, Greece and France – through so-called multi-actor labs (MALs). Over four years, more than 200 stakeholders from main economic sectors in each region engaged in the newly developed MAL approach. The MALs were assessed using a structured evaluation framework (Luederitz et al. 2017) and proved to be an effective approach for local capacity building and systemic understanding of each region.

Challenges in advancing impact
Erisman et al. (2024, in this issue, pp. 64–71) introduce insights from ten participatory labs, derived from structured self-reflection in a Community of Practice engaged in "Labbing". The authors outline four principal challenges: 1. measuring the impact of labs, 2. fostering impact within and beyond projects, 3. ensuring impact across different contexts, and 4. dealing with positionality and power dynamics. They introduce three generic strategies to tackle these challenges – capacity building, trans-local learning and reflexivity – supported by examples.

Klaever et al. (2024, in this issue, pp. 72–79) shed light on the conflicts that RwLs can provoke when promoting a mobility transition, drawing on insights from a project to temporarily redesign a public space in Berlin. Based on in-depth interviews, they categorize procedural, distributional and identity types of conflict and identify the influence of process design on their development. By highlighting the unintended adverse effects RwLs can have, they bring issues of conflict, power, and legitimacy to the forefront.

Jung and Wentland (2024, in this issue, pp. 80–86) examine how actors engaged in mobility experiments in local transition governance manage uncertainties and ambiguities of measuring success. Focusing on discursive strategies, the authors analyze how governments and other local actors collaboratively negotiate success and continually define and redefine what success means. The paper sensitizes that success cannot be solely judged by measurable impacts but should be understood within the context of each experiment's unique role and function for local governance actors.

Korzhenevych (2024, in this issue, pp. 87–93) examines the explanatory approach employed by 20 sustainability-oriented real-world experiments to uncover the logic and methods used to demonstrate the validity of research results. The author distinguishes between two approaches to induce causal inference between experiments and impacts, a process approach and a variance approach. He discusses potential biases, associated implications, and proposed solutions for each approach.

Methodologies for systematic analysis of impact
Wiefek et al. (2024, in this issue, pp. 94–101) propose a formative accompanying evaluation framework designed to enhance the

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impact orientation of RwLs, and present findings from testing it in two empirical projects. This framework combines a Theory of Change, a monitoring concept, and a continuous data collection, reflection and adjustment process. In the cases, ongoing monitoring and reflection sharpened the focus on desired outputs and processes, while the introduction of specific evaluator roles fostered professionalization and clarity of the evaluation.

Wanner et al. (2024, in this issue, pp. 102–109) used an evaluation approach rooted in Giddens' structuration theory for the RwL *Wuppertal-Mirke* and various subprojects. Their framework comprises four structuration modalities, namely interpretation schemes, norms, allocative resources, and authoritative resources, which together enable and constrain agency. These modalities have been operationalized, demonstrating the framework's effectiveness in evaluating co-creative city-making processes.

Franck et al. (2024, in this issue, pp. 110–115) are based on the case of a non-profit foundation-based RwL, called social design lab, with a focus on social innovation and design methodologies. They report on the design of an impact observation strategy that has been developed to track even smallest impacts, so-called impact particles, and intangible impacts in real-time. This formative self-evaluation strategy supports the design processes in the lab by providing feedback for iterative learning processes.

Schäpke et al. (2024, in this issue, pp. 116–124) propose the concept of leverage points as a heuristic to guide discussion and reflection on the impact of RwLs. They explore the core logics of interventions and various realms of leverage as analytical categories, applying them to reflect on two RwLs, *District Future* in Karlsruhe and *Wuppertal-Mirke*. The authors argue for a balanced approach to impact across leverage points, combining targeted interventions with open-ended engagement processes, and linking experiments at the material with those at the design and intent level of systems.

Concluding remarks

As this Special Issue shows, understanding impact is a central building block for RwLs in their goal to drive a Great Sustainability Transformation. The contributions herein provide a comprehensive examination of impact from a wide range of perspectives, enriching the dialogue around this complex subject. Authors show the impacts achieved by exemplary RwLs in recent years. At the core are new forms of governance and collaboration, learning, trust and capacity building, and the development of institutions, organizations and networks. In essence, RwLs have paved the way for new ways of thinking, acting and collaborating. Related, manifest impacts included physical and socioecological changes. Accordingly, there is evidence on various, complementary ways in which RwLs contribute to societal change towards sustainability.

Authors also shed light on the mechanisms and enabling conditions of impact generation, including regulatory experimental space, reflexivity towards directionality, and the development of legitimacy and social cohesion as social foundations of RwL work and impact. The contributions deepen our insights into the typical challenges of understanding and realizing impact, emphasizing the role of politics, power and conflict in RwL work, and the tension between context-specific RwL success and aspiring impacts across contexts. Two trends can be identified as ways forward: First, to seek a detailed understanding of conflicts and underlying processes, as well as of the rationales for attributing success to RwLs, both from the perspective of societal actors engaged in RwLs and in terms of scholarly analysis. Second, authors highlight the benefits of enhancing capacities and institutionalizing opportunities of RwL actors to address respective challenges, including enabling reflexivity on power dynamics and catalyzing cross-sectoral, cross-case learning.

Moreover, some authors develop methodological advances: they show show how RwLs can benefit from established system-thinking and social theory frameworks to understand and design RwL processes and impacts from a broader perspective. Integrated, reflexive and in-depth approaches to formative monitoring and evaluation to reflect and adjust RwL processes are outlined.

However, these contributions also show that – just as RwLs are a young format – the study of "impacts of real-world labs" is to some degree still in its infancy within academic research. Moreover, it becomes evident that the intrinsic characteristics of RwLs (multi-actor co-production, procedural openness, iterative learning, and operation within real-world social and political contexts) are precisely what makes it difficult to define, plan or measure RwL impact. It almost seems as if good practice in RwL work and impact assessment are to some extent contradictory. This makes it all the more important to develop the theoretical foundations of RwLs, alongside further empirical research and capacity building,

For a deeper comprehension of RwL impacts in the future, four institutional aspects are required: 1. impact research conducted by multi- and interdisciplinary teams, 2. funding programs that explicitly include impact assessment 3. alliances of similar RwLs that facilitate comparability and mutual learning, and 4. the establishment of RwLs not as time-bound projects but as permanent research infrastructures capable of ongoing impact monitoring and assessment long after specific experiments have been completed.

We aspire that this Special Issue significantly contributes to advancing the understanding and realization of future impacts of RwLs towards sustainability transformations.

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