



Building capacity for sustainability transformations through transdisciplinary experimentation: Empirical evidence from a novel methodology deployed in 7 countries

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ABSTRACT

In 2022, the Intergovernmental Panel on Climate Change (IPCC) established that global greenhouse gas emissions trajectories are not on track to limiting warming to less than 2 °C above pre-industrial averages (IPCC 2022a). Given that broader progress towards ambitious climate change and sustainability goals remains incremental, a whole-of-society approach, including transformative innovation in the private sector, is required to trigger the necessary changes within deeply unsustainable social and technical systems. This paper develops and illustrates an evidence-based process to enable organizations to foster sustainability transformations beyond a firm's traditional boundaries. Based on 42 rich qualitative cases studies, a range of transdisciplinary capacity-building events in 7 countries, and 13 co-produced experiments, we develop the logic behind, and empirically test, an iterative process that maps the sustainability pathways of small firms, builds capacity for transformations among them, triggers new experiments, and reflects upon how these actions can and are influencing broader transformations towards sustainability. We find that small businesses have the potential to facilitate sustainability transformations, both within their organizational boundaries, and within the broader ecosystem of which they are a part. We find that transformative sustainability practices are relational (in that they rely on a web of relationships among many 'ecosystem' actors rather than a single organization) and may be fundamentally altered by transdisciplinary co-production methodologies. Ultimately, we found an iterative relationship between capacity and experimentation: capacity was built *through* experimentation, which then revealed potential capacity gaps or needs that could be remedied through iteration.

1. Introduction

Climate change represents a vast suite of interconnected and rapidly increasing risks (Pescaroli and Alexander, 2018), which challenge the most fundamental tenets of contemporary societies: our systems of production and consumption, the design and function of cities, and our capacity to address other sustainability priorities such as preserving biodiversity, conserving water, and securing health and well-being for all (IPCC 2022a). While the pace of the transition towards an energy system rooted in renewables has exceeded many expectations (including the rapid decline in the cost of utility-scale solar and storage, for instance – see He et al., 2020; Luderer et al., 2022) and the rapid

proliferation of climate change policies at virtually all scales of governance (Eskander and Fankhauser, 2020), global emissions remain too high to constrain warming to less than 2° Celsius above pre-industrial average temperatures (IPCC 2022b). This necessitates deeper thinking and more rigorous exploration of both the sources of inertia driving unsustainable development pathways (Burch et al., 2014) and the leverage points that might trigger accelerated sustainability transitions (Abson et al., 2017).

Three dimensions of this challenge appear to exert enormous influence over the pace and scale of desirable sustainability transitions. First, policy and governance gaps exist at multiple levels of government. Climate change (both adaptation and mitigation) are often considered in

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isolation from intersecting policy priorities, such as emergency management, biodiversity conservation, human health, trade, and natural resource extraction (Laurens et al., 2021; Wamsler et al., 2020). Some governments are making significant efforts to apply a “climate lens” across decision-making in many domains, with progress, for instance, in assessing climate hazards and public health vulnerability (Fox et al., 2019). In many countries, however, there has been modest tangible success in directly connecting the task of greenhouse gas reductions to adaptation (e.g. ensuring that rebuilding after disasters adheres to low- or zero-carbon building standards, widely deploying nature-based solutions in a way that quantifies both the sunk carbon and the benefits for public health during heatwaves) (Hurlimann et al., 2021; Waters and Keele, 2022). Indeed, while Canada launched its first National Adaptation Strategy in 2023 (a nation-wide effort engaging dozens of experts and fostering a suite of public consultations), prescribed actions that connected adaptation and mitigation remained extremely rare (Government of Canada, 2023). As a result, maladaptation becomes more likely, “tunnel-vision” can lead to a focus on responding to ever-evolving emergencies while failing to consider how the way we respond to those emergencies might in fact lock communities even further into high carbon pathways, and crucial opportunities to deliver on multiple priorities simultaneously are lost.

Second, the core challenge at the root of sustainability transitions (and progress on climate change more specifically) continues to be broadly perceived as a technical one, rather than a social or political one. Investments focus overwhelmingly on supply side (e.g., renewable energy) solutions over demand-side (which are deeply behavioural as well as technical) (Creutzig et al., 2016). Interest in geoengineering is rapidly growing (Raimi, 2021), holding out the tantalizing possibility that a relatively modest investment will erase the need for much messier, politically fraught, and culturally contentious shifts in the values that underpin production and consumption. This has at least two powerful repercussions: public imagination is limited to a reproduction of the current political economy (Nightingale et al., 2019), simply relying on different energy sources to fuel the same lifestyles and governance models; and progress toward sustainability is dramatically slowed while available technical solutions fail to spread and grow (see for instance the now seminal ‘stabilization wedge’ analysis performed over two decades ago, demonstrating the availability but limited uptake of energy transitions technologies) (Pacala and Socolow, 2004).

Third, key sets of actors, including the private sector at large but particularly small- and medium-sized enterprises, remain largely ignored in the public discourse (and scholarship) around the governance of sustainability transition pathways (Luederitz et al., 2023; Burch et al., 2022). This rests in part on a narrow conception of the role of businesses in society (as simple profit maximizers) (Westman et al., 2019) and a propensity to view governance as largely the domain of traditional government actors rather than an evolving and shared project among civil society, private, and public actors (despite decades of research to the contrary). This manifests as a general lack of support for sustainability upskilling, innovation, and transitions among key sectors of the economy, such as smaller businesses and less carbon-intensive industries. SMEs have the potential to facilitate sustainability transformations, both internally and at the ecosystem level (Stubbs et al., 2024; Westman et al., 2023). To enable those transformations, we need to first understand sustainable business practices and models, understand and build particular capacities that facilitate transformation (Orr and Burch, 2025), and finally experiment to accelerate change.

Reflecting on the above challenges, this paper presents methodological and conceptual insights derived from a multi-year, multi-country empirical research project (running from 2019 to 2026) called TRANSFORM. This paper presents empirical findings gathered throughout the course of the TRANSFORM project, which aimed to uncover and build the capacities needed for small businesses to experiment with potentially transformative sustainability practices and business models (see for example Burch et al., 2022; DiBella and Burch,

2025). We focused on the following three questions:

- What barriers and enablers do organizations (particularly small and medium-sized enterprises) encounter as they develop, implement, and refine sustainable business practices and models?
- What capacities are needed to adopt sustainable business practices and models? How are these capacities built?
- How do sustainability experiments unfold? How might a transdisciplinary co-production process build specific capacities in organizations, and the ecosystems that encompass them, to undertake new sustainability experiments?

To answer these questions, we first developed, refined and tested a three-step iterative process that 1) mapped pathways followed by businesses to develop and implement sustainable business practices, 2) built capacity for sustainability experiments in small firms, and 3) actively co-created new experiments in partnership with organizations of various sizes, monitoring and evaluating these experiments over time. Our starting point was a focus on small- and medium-sized enterprises, but we expanded out to other organizations and the ecosystem (Jacobides et al., 2018) within which they operate. Thus, our empirical work has two units of analysis: both the individual small firm and the broader ecosystem.

We offer two multi-faceted contributions. The first is *methodological*: we developed, refined, and tested a three-step iterative process for 1) the articulation and visualization of the pathways that organizations followed as they designed and implemented new sustainability practices; 2) the cultivation of the capacities among both businesses and supporting organizations to explore transformative approaches to sustainability; and 3) using an enriched version of the pathway mapping methodology from (1), designing new sustainability experiments as a transdisciplinary co-production exercise. This offers a clear contribution to empirical transdisciplinary sustainability science by focusing on small- and medium-sized enterprises (which are underrepresented in the sustainability science literature), while also explicitly demonstrating the value of connecting capacity-building and experimentation through an iterative procedure.

The second contribution of this paper is *conceptual*: based on the empirical data gathered through the three iterative steps above, we establish the practical (in terms of an organization’s structure, function, and purpose) and theoretical links between pathway mapping, capacity-building, and experimenting. We consider the implications of this process for policy-making and implementation, given ambitious climate targets and mounting pressure on the private sector to demonstrate deeper commitments to sustainability. By co-developing an adaptive learning process, we contribute to scholarship on social learning and adaptive governance, building the capacity to test, document, and redirect experiments (König, 2018).

Rather than isolating our exploration of the existing scholarly literature on sustainable business practices, capacity-building, and experimentation from the project’s methodology, as is traditional, in the sections that follow we integrate our theoretical work with the empirical design that we created. This serves to directly tie our conceptual and methodological contributions together, while following the three-step, iterative process laid out in the TRANSFORM project. For each phase of work, we offer an illustration of the method, and a synthesis of key findings. We conclude with insights for theory and practice, focusing on the connections between capacity and experimentation at the ecosystem level, and the implications for the practice of transdisciplinary sustainability science.

2. Empirical context

The TRANSFORM partnership began as a collaboration among sustainability scientists, climate change governance scholars, and entrepreneurship experts located in Canada, the United States, Australia,

Germany and Sweden. Over time, the geographic range of the project's empirical work extended to include Mexico and Colombia, based on researchers' expertise and networks.¹ Each country varies in its sustainability and innovation policy context, regulatory approach, the presence or absence of incentives for business, and its entrepreneurial culture. Canada, for instance, offers Clean Economy Investment Tax Credits to accelerate the uptake of net-zero emissions technologies and support cleaner manufacturing (Government of Canada, 2024), while also piloting the Dutch Energiesprong model of accelerating deep energy retrofits in neighbourhoods (NRCan, n.d.). Through the Green Industry Leap and the Climate Leap, Sweden likewise incentivizes research and development, testing, and spreading of energy efficient and low carbon technologies (Business Sweden, 2022). It is notable, however, that these incentives overwhelmingly target technological innovation, rather than the behavioural, social, and organizational innovations that give rise to it. Prior to engaging in empirical work, researchers first mapped the sustainability governance context in each case study area to prepare for interviews, workshops/experiential learning, and experimentation activities.

Despite this geographic diversity, our approach to engaging with firms across these diverse contexts was aligned: we first built deep relationships with civil society organizations and business networks that connect and enhance sustainability efforts in the private sector (such as Sustainable Waterloo Region (CAN), Sustainability Victoria (AUS), and Sustainability First (USA)). These organizations shared examples of leading sustainability innovators in the small business sector, and offered introductions to knowledgeable staff members. We then selected cases based on: 1) diversity across Sustainable Development Goals, sectors, and sizes; 2) demonstrated sustainable business practices and/or business models; and 3) willingness to invest considerable time and effort in pathway mapping, capacity-building and experimentation procedures. Specific sampling logic and methods are presented in each of the sections that follow.

3. Pathway mapping of sustainability practices and the enabling ecosystem: logic, methodology, and insights from 42 cases in 7 countries

3.1. Sustainability entrepreneurship and the enabling ecosystem

The private sector plays a crucial role in addressing environmental and social harms, and in enabling a transition toward more sustainable development pathways. Sustainability entrepreneurship represents a delicate proposition: that firms can discover and exploit opportunities for profit that also deliver meaningful environmental and social benefits. In their classic definition, Schaltegger and Wagner (2011) describe sustainability entrepreneurship as a set of activities that generate "innovations aimed at the mass market and providing benefits to the larger part of society," addressing unmet needs of stakeholders. Over time, sustainability entrepreneurship has evolved to encompass activities that may challenge conventional market structures and undesirable consumption patterns, replacing them with more sustainable (that is, environmentally regenerative, socially equitable) practices over time (Rosário et al., 2022). Examples are diverse, and range from zero-waste refill stations (Zaman, 2022), to inclusive agribusiness models that aim to more widely share access to finance and profits, while also potentially increasing food security (van Westen, 2019).

These innovations, however, do not emerge in an isolated fashion within individual firms. Individuals and businesses interact with, and are supported by a wide range of organizations, ideas, institutions, and resources that support and influence the progress they might make on sustainability (Klewitz et al., 2012). We think of this as a 'business

ecosystem' – a vibrant web of structural and relational interactions ranging from supply chains, shared ideas, and partnerships among firms, to policy interventions, regulations or tax incentives developed by government (DiBella and Burch, 2025). The business ecosystem provides support and enabling functions to businesses, including business services (e.g. lawyers, accounting, consulting), financing, capacity building (e.g. education and workforce development), networking, marketing, and material provision (cf. Hileman et al., 2020; Ma et al., 2018).

From this more systems-oriented perspective, the capacity to realize sustainability transformations goes beyond the skills and abilities of individuals and organizations to include a broader ecosystem of actors and relationships which collectively supports and enables SMEs to act (Orr and Burch, 2025). For example, formal and informal networks enable businesses and other organizations to share knowledge, expertise, tools, and resources, and to act in ways that, on their own, individuals and organizations would not be able to. Moreover, changes in businesses are interdependent with broader shifts of the business ecosystem. Changes at the ecosystem level would "radically alter the context" in which businesses operate and could occur through norm shifts, new actors and relationships, policy, funding, and drivers such as technological or climate changes (Waddock 2020, p195).

The first step in the TRANSFORM process was to empirically explore the process followed by sustainability-oriented entrepreneurs as they design and implement new practices, while applying a systems lens that might reveal connections between this process and the broader ecosystem of actors. In the sections that follow we present this methodology and results that emerged.

3.2. Approach and methodology

Organizations naturally follow multi-step, iterative, and occasionally chaotic pathways as they conceive of and implement new practices. These pathways are rarely linear, facing barriers, diversions, and course changes (Forrest and Wiek, 2014). This is true of sustainable practices as well – actions and strategies that reduce resource use, regenerate a degraded environment, adapt to a changing climate, and encourage social equity and inclusion.

The pathway mapping process developed by the TRANSFORM team had four specific aims: 1) to define and delimit specific sustainable business practices; 2) to identify the various steps that were taken in the lifespan of that practice (from conception to implementation, monitoring, and refinement); 3) to identify key actors in the ecosystem surrounding the organization; and 4) to explore the relationships between actors, revealing key moments of intervention, thereby connecting a specific practice to the broader ecosystem out of which it emerged.

Organizations were selected that: were located within the geographic areas covered by the TRANSFORM project (Canada, the United States, Mexico, Colombia, Germany, Sweden, and the United Kingdom); fell within the Canadian definition of a small- or medium-sized enterprises (ie up to 499 employees); and had demonstrated experience and success with multiple sustainability practices, identified through a combination of internet research (encompassing company websites, published materials, social media profiles) and advice from trusted intermediaries – locally influential and connected organizations that serve and connect businesses with sustainability ambitions (Kundurpi et al., 2021). We elected to be sector agnostic (e.g., engaging with firms from manufacturing, retail, hospitality, agriculture, and professional services among others), which allowed distilled insights to be tied more closely to organizational structure, behaviour, values, and community-embeddedness, rather than focusing on specific technical dimensions of a particular industry's sustainability challenge(s).

Semi-structured interviews were conducted across 42 organizations involving multiple individuals within the organization, as well as individuals within the 'ecosystem.' A semi-structured interview script was designed to explore a business's main sustainability practices and delve

¹ Full list of businesses engaged through this project can be found at www.transformcities.ca

further into secondary sustainability-oriented practices.

The interview script guided the research team to explore: the origin and evolution of sustainability practices within the business and identify the relevant actors; the moment and role those different actors had played in enabling or arresting these practices (either by providing information to design a practice, establish monitoring or evaluative process, but also more specific financial resources which align to the establishment of sustainability-informed activities). Fig. 1 provides a generic example of the key elements that were mapped during this process. The categories that were included were drawn in part from previous work in this field (cf. Forrest and Wiek, 2014), but inductively refined based on the data gathered. Interviews were translated to English (if necessary), transcribed and coded using Nvivo qualitative analysis software.

Preliminary pathway maps were developed by researchers based on initial interview data. These maps were then verified and enriched through a second set of interviews with the key informants. Across the 42 cases, the pathway maps yielded 84 distinct sustainability practices, ranging from community-based ecosystem management, to inclusive labour practices, urban edible gardens, construction waste management, and water recycling, among others.

3.2.1. Illustrative case: 100 km Foods, Ontario, Canada

100 km Foods, a company based in Ontario, Canada, is a wholesale local food distributor that builds relationships with local farmers, focusing particularly on sustainable or regenerative food production, and connects them with restaurants and chefs in the surrounding region. This sustainability-oriented food sourcing model included fair labour practices, reducing the distance that food travels, and building the customer base for products from regenerative agriculture farms. The pathway map below (Fig. 2) illustrates key moments in the design of 100 km Foods' central sustainable business practice, including multiple design stages, networking, and implementation. Interviews revealed that key actors in this ecosystem included social impact investors, local research organizations, and a food community centre (providing significantly discounted or free fresh food to vulnerable groups), along with the typical constellation of suppliers and customers. One of the most significant enabling factors that emerged through the interviews was the vision of the co-founders and their commitment to regenerative agriculture in the region. This permeated the architecture of the firm and influenced its research and advocacy work in the field. A significant arresting factor identified by interviewees from this firm suggested balancing investments in better technology (eg low carbon transport for food from farms to restaurants) with competing priorities (such as a living wage) was challenging. Likewise, 100 km Foods faced considerable barriers with investors: most venture capital firms sought near-term double-digit returns on their investment, with little concern for social

impact or longer-term benefits. Pricing of products remains a challenge for 100 km foods, given that labor-intensive regenerative practices cost more than typical commercial food production, wages in rural areas must compete with higher salaries in the nearby city of Toronto, and existing food system infrastructure is generally designed to facilitate transport and storage of large quantities of food over large distances.

3.3. Key findings from pathway mapping

While the data generated through the pathway mapping process could give rise to multiple analytical insights, chief among the themes was the importance and diversity of both enabling and arresting factors (and the interactions between them). Interviewees suggested that these fundamentally influenced the nature, scale, and pace of sustainability-oriented innovations, and also highlighted the importance of the ecosystem of actors in which the firm was embedded. Interviews across the 42 cases unearthed a diverse range of enabling and arresting factors (Table 1) that influenced the success with which firms designed and implemented new sustainability practices. These were both internal and external to the organization and broadly fell into four themes: skills, knowledge and human resources; culture and leadership; technical and financial dimensions; and policy, governance, and organizational structure. Future work will synthesize data from the pathway maps to establish archetypal pathways that firms follow, and uncover the capacities and policies that enable each one.

Data gathered through semi-structured interviews, and synthesized and visualized using pathway maps, revealed the actors who are actually involved in the design and implementation of sustainability practices, many of which are excluded from current conceptions of a business ecosystem (Jacobides et al., 2018; Moore, 1996). The pathway map itself became viewed by researchers as a boundary object that helped to both establish relationships between actors in the ecosystem as well as a shared definition of the problem that the organization is attempting to solve through the practice (or the aspiration that they were reaching for). Co-producing the problem definition is a core tenet of transdisciplinary sustainability science (Lang et al., 2012), and ultimately gave rise to a more relational view of sustainability transformations (West et al., 2020) that shaped later stages of research (and will be discussed in greater detail in the sections that follow).

The pathway traced the process by which value is created, and how innovation, connection, and experimentation drive that value. Ultimately, we generated lessons about the nature of change, rather than simply the technical ingredients of a sustainable business practice. As such, the findings are applicable to a much broader range of organizations and sectors.

Three key patterns emerged in pathway mapping data. First, we found that many enablers were social (behavioural, organization,

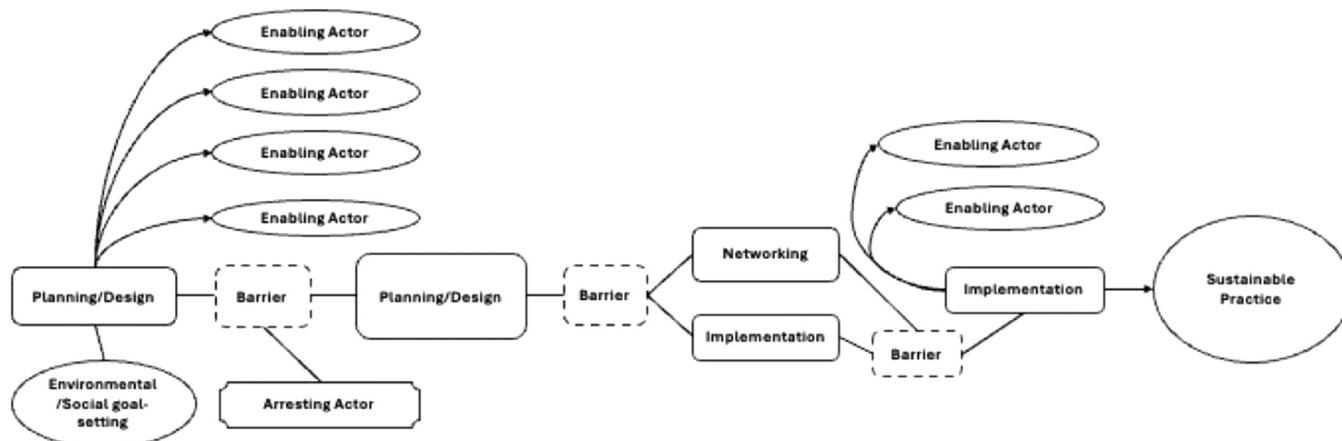


Fig. 1. Sample pathway map, including key steps, barriers, enabling actors and arresting actors.

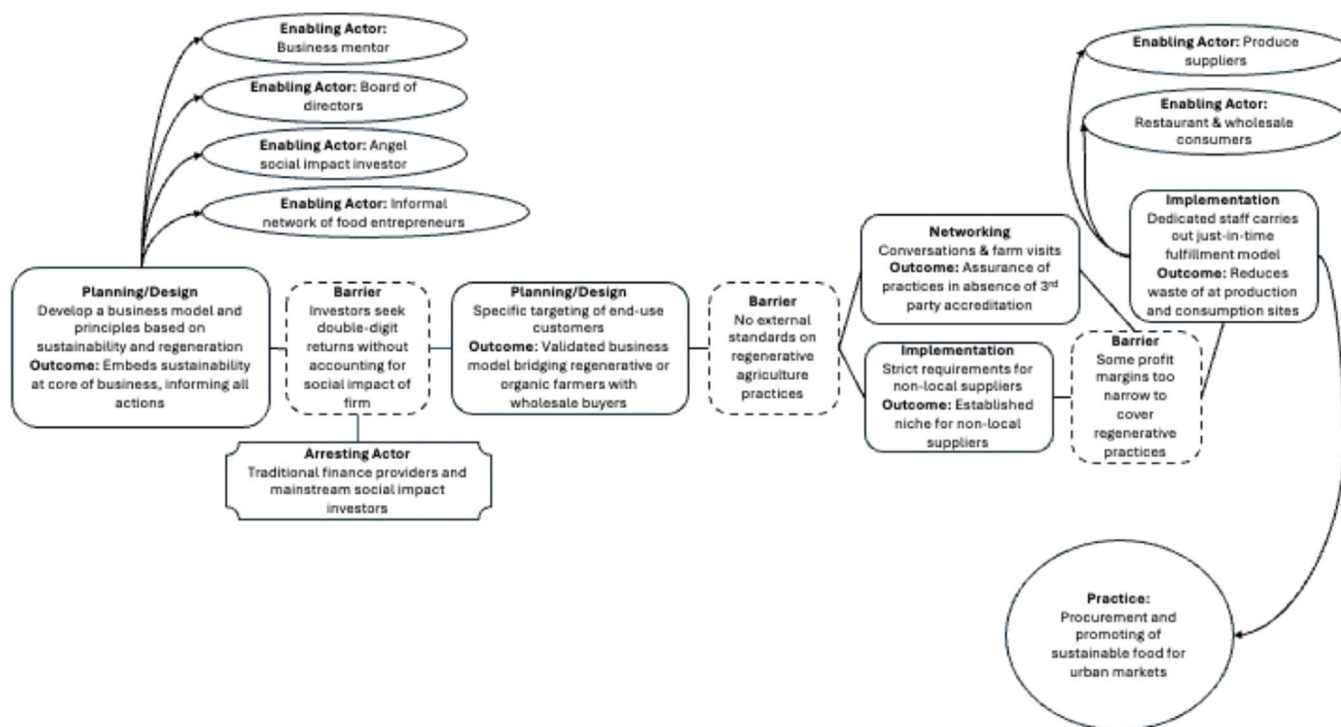


Fig. 2. Pathway map for 100 km Food's practice of procurement and promoting sustainable food for urban markets. Full pathway map is available at <https://transformcities.ca/practice/procurement-and-promoting-of-sustainable-products-for-urban-markets/>.

Table 1

Enabling and arresting factors identified through interviews in 42 businesses across 7 countries. (I) denotes a factor that is internal to the firm, while (E) denotes and external factors. Factors are clustered according to theme.

Enabling Factors	Arresting Factors
Skills, knowledge, and human resources	
Staff members adopting sustainable behaviours (I)	Lack of technical capacity to develop disaster risk reduction or sustainability plans (I)
New ideas generated by staff (I)	Skilled labour shortage (E)
Expertise and training (I)	
Multi-generational knowledge (I)	
Capacity-building events (E)	
Diversity and depth of networks (E)	
Culture and leadership	
Founders'/leaders' industry experience, values and vision (I)	Limited market demand or inertia behind unsustainable business models (E)
Clients & customers who share values (E)	
Growing market demand for sustainable products (E)	
Collaborative firms in the industry (E)	
Technical and financial	
Significant energy and material cost savings (I)	Financial resources -extra costs associated with sustainable practices (I)
Technical solutions (eg. reverse osmosis water treatment or energy monitoring) (I)	Unsustainable industry standards (E)
Grants and in-kind funding, often provided by government or research institutions (E)	Absence of key infrastructure in communities (eg Composting facilities etc)
Policies, governance and organizational structure	
B-corp policies and resources influencing governance and decision-making (I)	Trade-offs between regulations and sustainable outcomes (E)
Operational 'green team' with formalized strategy (I)	Unhelpful, costly, or onerous certification schemes (E)
Employee ownership, including cooperative models (I)	Hostility or corruption in government (E)
3rd party certifying bodies (E)	

values-based) and relational, rather than purely technical or financial. While cost savings and technical skills were frequently raised as important drivers of success, participants more frequently cited leadership, customer values, sharing of knowledge across silos, and new governance models as being essential. Indeed, these human factors can serve to free up the financial resources to try new sustainability experiments, and build the relationships necessary to share technical skills – thus serving as precursors to innovation. This pattern is not unique to firms, and has been noted in the governance of climate change in urban contexts as well, for instance (Goudsblom and Clarke, 2025).

Second, we found a tension between helpful certification schemes (like B-corp status) that offered nuance and depth to how sustainability was pursued within the first, and certifications that were onerous, misaligned with local values, or conflicting with other priorities. This echoes the concerns identified by other scholars, who suggest that 'certification dissonance' emerges when the aims of the certification conflict with businesses' perceptions of what is fundamentally sustainable, or the demands of the businesses' customer base (Flagstad et al., 2022). This dissonance may lead to greenwashing, lack of transparency, or abandonment of the certification scheme altogether, thereby inhibiting potential progress towards more sustainable business practices.

A third crucial insight from this stage of work shaped the next steps in our research project: that sustainability transformations do not occur in isolated firms, but rather in the ecosystem within which a firm is embedded. These ecosystems are bound together in part by networks, explicitly fostered by civil society and industry associations, which enable the sharing of technical skills, the deepening of trust, and broadly building capacity. The pathway mapping process laid the foundational building blocks for the capacity-building activities that came next in the project lifecycle. Indeed, the conversations had with interviewees can be viewed as planting the seeds of capacity building, as we encouraged reflection on the nature of barriers, enablers, transformation, and the extent to which distinct practices interweave with each other and shift the landscape of the firm as a whole. For instance, what skills and competencies are needed to cultivate and embed a shared vision of deeply sustainable business activities? How might transdisciplinary

scholars engage not simply with individuals firms, but with ecosystems, to trigger or accelerate sustainability transitions? In the sections that follow, we will synthesize our approach to capacity building for sustainability transformations with ecosystem dynamics in mind, followed by an exploration of the co-designed experiments that followed.

4. Capacity-building: beyond technical and cognitive dimensions to capacity of the ecosystem

4.1. A model for building absorptive capacity

A multi-faceted model for building absorptive capacity was used in the TRANSFORM program, including a specific theory of change, the concept of absorptive capacity and the concept of progressive capacity-building. The model is described in detail in a practical guide (Wiek, 2021) and in the synthesis report (Wiek et al., 2025). Here, we briefly outline the key components of the model.

First, the capacity-building activities were primarily intended to build capacities in SMEs to adopt (and maintain) sustainable business practices and models. To this end, as indicated above, in addition to building such capacities in SMEs, a number of activities were intended to build capacities in organizations to adopt functions such as specific policies, financing options, training that help SMEs to adopt (and maintain) sustainable business practices and models. While the broad focus here was on SMEs (as in the pathway mapping activities), larger firms, and organizations in the civil society sector were also involved in the capacity building activities (and likewise in the experimentation phase of the work, explored in Section 4.)

Second, for operationalizing capacity we used the *concept of absorptive capacity* (Fig. 2). This concept highlights the importance of an enterprise's or organization's ability to adopt, rather than invent, novel practices, models, or functions. Absorptive capacity can be structured into (1) competence of individuals and groups; (2) organizational factors; and (3) inter-organizational factors (cf. Aboelmaged and Hashem, 2019). For simplification, we focus in the following description on the absorptive capacity of SMEs; yet, the concept analogously applies to other organizations as well. *Competence* includes knowledge, skills, and attitudes (e.g., confidence or commitment) of leadership and staff in SMEs to adopt sustainable business practices and models (Fouquier and Wiek, 2019). *Organizational factors* are plans, policies, standard operating procedures, organizational habits, funds, training opportunities, etc. in SMEs that are important carriers for adoption of sustainable practices (Klewitz and Hansen, 2014). *Inter-organizational links*, e.g., for inter-organizational learning, enable an SME to tap into adoption resources beyond the own organization (Dzhengiz, 2020). These links support an SME in identifying sustainable practices, technologies, or model innovations; becoming aware of supportive or hindering external factors such as new regulations or policies; learning from other businesses' experiences (avoiding mistakes); or accessing additional financial resources. This connects directly to the concept of the ecosystem introduced in Section 3 of this paper.

Third, we used the concept of *progressive capacity building* for building absorptive capacity in SMEs (Fig. 3). This concept is grounded in

(cognitive) apprenticeship, experiential, project-based, and other pedagogical approaches. The basic idea is that absorptive capacity, i.e., competence, organizational factors, and/or inter-organizational links in SMEs is built gradually through three distinct phases (even if they might overlap in many cases). Over the course of the three phases, ownership for the sustainable business practices and models is successively transferred to the SME. The first phase pertains to *familiarizing* the SME with the respective sustainable business practices and models, e.g. through presentations, readings, and so forth. From this rather passive learning mode, the second phase moves into a more active learning mode by enabling SMEs to *experience* sustainable business practices and models, through site visits, virtual field trips, shadowing, etc. The last phase supports the SMEs in *experimenting* with sustainable business practices and models; generally, this phase includes coaching and mentorship activities. Going through more than sequences allows for building (lasting) absorption capacity, as opposed to just participating in one (exemplary) adoptive process.

The various components of absorptive capacity are built in different ways through the three phases. Knowledge of sustainable practices and models is assumed to be primarily built through getting familiarized and experiencing; skills through experiencing and experimenting; and attitudes (commitment, confidence) built through experimenting.

4.2. Capacity-building activities

41 capacity-building activities have been conducted in the TRANSFORM program (to date) that cover a range of topics (practices, models, and functions) addressed, goals pursued, settings adopted, and so forth. Capacity-building activities were carried out in Canada, Germany, the United States, Sweden, Mexico, and Australia, between 2019 and 2024. The design of the activities was diverse: we carried out large multi-actor participatory visioning exercises, multi-week summer schools, intimate workshops that incorporated field visits and experiential learning, and more. In the following sections, we present an illustration of the capacity-building activities carried out by TRANSFORM, which focused on building competence in SMEs for adoption of a sustainable business model.

4.2.1. Illustrative activity 1 – Capacity-building activity for SMEs on a sustainable business model

A full-day training for (future) entrepreneurs of SMEs was carried out in Arizona, United States entitled "Building Capacity for Sustainable Employee-owned Businesses and Worker Cooperatives" (Forrest et al., 2019; Forrest et al., 2023). It was planned and conducted by the team from Arizona State University's Sustainable Food Economy Lab and a cohort of students from a graduate course, co-taught by two professors, a postdoctoral researcher, and a theater instructor during the summer term 2019. The training was offered in Phoenix, Arizona on April 14, 2019, and lasted for 6 h. 16 entrepreneurs participated.

The capacity-building activity addressed (future) entrepreneurs in their function as (future) leadership and workforce. It was a formal capacity-building activity, namely, a training with defined learning objectives, dedicated learning activities and a pre-post evaluation

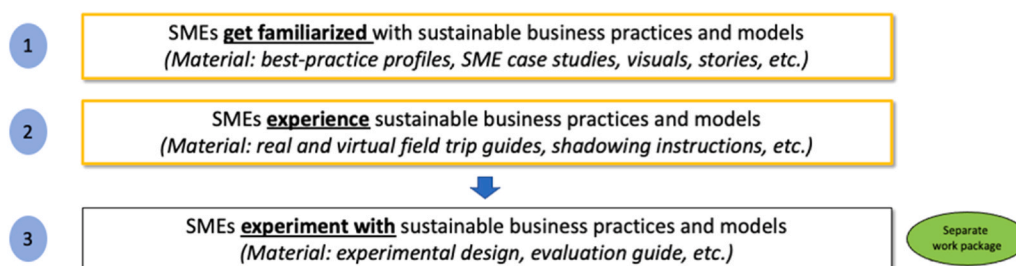


Fig. 3. Concept of progressive capacity building with three phases (and educational material).

approach to measure learning success (Forrest et al., 2019). The overarching learning objective was to convey basic knowledge, skills and attitudes for converting to, starting up, or participating in sustainable cooperative businesses (cooperative business model, specifically worker cooperatives); as well as to convey basic knowledge of select sustainable business practices. The specific learning objectives were for participants to be able to: define and apply the characteristics of a worker cooperative; distinguish a worker cooperative from a conventional business and identify the success factors; define and apply the characteristics of a sustainability-oriented worker cooperative; be motivated, inspired, and empowered to form a worker cooperative; be connected to like-minded peers and support groups. A few other (meta-) goals included to create material for future trainings and to develop skills for students in carrying out trainings.

The cooperative business model and select sustainable business practices were conveyed in three modules (learning content): (i) basics of worker cooperatives, including differences between worker cooperatives and investor- or other-owned businesses, main benefits for workers and communities, seven cooperative principles that guide cooperative businesses, examples of successful worker cooperatives; (ii) operations in worker cooperatives, including procedures, rights, responsibilities, and required skills for cooperative decision making, financial management and member recruitment; and (iii) sustainable businesses practices in worker cooperatives. While not the primary learning objective, the training also familiarized participants with a small set of sustainable business practices, including use of renewable energy, alternative transportation (delivery of products by bike), sourcing of local (organic) ingredients, recruiting a diverse workforce, community building, and some others.

As opposed to rather passive modes of capacity building (with limited effectiveness), the training did not just present evidence and examples of the (reconstructed) sustainable business model and the sustainable business practices but facilitated ‘deep’ or ‘embodied’ learning. To this end, the training used immersive, interactive methods to simulate professional situation to facilitate ‘learning by doing’. Guidance was provided by an instructor experienced with theater methods (Theater of the Oppressed) and role play. The basic inspiration for this setting came from social work programs that hire actors to simulate (and control) professional situations for examinations (cf. Foucrier and Wiek, 2020). In the training, small groups worked through the three modules, guided by a moderator, engaging in facilitated interaction, role-play, and improvisation as well as videos, discussions, and reflections.

A pre-post survey with all participants, complemented with observational protocols by student assistants, yielded as key learning outcomes (results): an increased level of knowledge about worker cooperatives and select sustainable business practices; basic level of skills in operations of a worker cooperative; increased motivation to learn more and apply the obtained capacities; as well as an enhanced network of entrepreneurs interested in engaging in cooperative businesses (Forrest et al., 2019).

Subsequent impacts of this training – beyond the impacts on participants - were the development of a structured training program in Phoenix (Wiek and Hartland, 2022); the founding of a consultancy specialized in delivering this program in Phoenix (*Thrive Consultancy*); the start-up of a cooperative food business in Phoenix (*Food Forest Cooperative*; Wiek and Albrecht, 2022), and the spreading of the cooperative business idea through different channels across Arizona (including a capacity-building partnership with *Local First Arizona’s* SCALEUP program). All of these subsequent impacts go beyond building capacity in the participants of the original training. They represent the greater effects of the training through building out and strengthening the entrepreneurial ecosystem that supports (many more) SMEs in adopting cooperative business models.

4.3. Key findings from capacity-building

The variety of capacity building activities carried out under the auspices of TRANSFORM generated a range of insights into the types of capacities that might enable or accelerate the design and implementation of sustainable business practices and modes (Table 2). The following table summarises the key findings from this phase of the work.

While these built capacities consistently emerged from the cross-case analysis of the 41 conducted capacity-building activities, they rarely occurred individually or disconnected. For the more comprehensive capacity-building activities (cf. 3.2.1.), we were able to reveal nested or complex built capacities. For example, the training program described above not only conveyed knowledge about the cooperative business model but also implementation skills (to some extent), motivation and confidence; all of which are essential and interconnected ingredients for adopting a sustainable business model. Capacity-building activities targeting SMEs often conveyed linked capacities of knowledge, skills and attitudes, manifesting in organizational capacities such as business

Table 2
Capacity-building outcomes from TRANSFORM project.

Components of absorptive capacity	Type of outcome (or proxy)	Outcomes of capacity-building activities in the TRANSFORM project
Competence of individuals and groups (knowledge, skills, attitudes)	Conveyed/acquired knowledge	<ul style="list-style-type: none"> • Knowledge of specific sustainable business practices • Knowledge about sustainable business models (eg cooperatives, employee ownership etc) • Knowledge about ecosystem functions (eg partnerships among organizations, trust, resource sharing etc)
	Conveyed/acquired skills	<ul style="list-style-type: none"> • Systems thinking, futures thinking etc • Implementation skills (cooperatives, sustainable growing skills etc)
	Conveyed/acquired attitudes	<ul style="list-style-type: none"> • Motivation/commitments <ul style="list-style-type: none"> o To learn more and to implement sustainable business practices and models o To create a new small business using sustainable business models • Confidence <ul style="list-style-type: none"> o To use systems thinking, futures thinking etc in business contexts o To implement sustainable business practices and models
Organizational factors (plans, policies, standard operating procedures, etc.)	Conveyed/acquired organization capacities	<ul style="list-style-type: none"> • Plans/concepts developed • Financial resources/funds • Policies changed/adopted • Training secured
Inter-organizational factors (ability to tap into adoption resources beyond the organization itself)	Conveyed/acquired inter-organizational capacities	<ul style="list-style-type: none"> • Connections with other likeminded SMEs (e.g. cooperative economy) • Connections among organizations in the ecosystem • New/extended mixed partnerships (e.g. Maricopa County Food System Coalition; among researchers to develop business ideas and support startups

plans/concepts developed. Capacity-building activities targeting supporting organizations of the ecosystem were rather light on conveying knowledge, skills or attitudes and rather yielded inter-organizational capacities that empowered organizations to deliver their support functions effectively. In some of these latter cases, we also saw a pattern of mutual enforcement across capacity-building activities. For example, the development of a public-private partnership resulted from several activities targeting inter-organizational capacities. These mutually enforcing activities eventually yielded sufficient support for publicly funding a private consultancy to regularly deliver training in cooperative business models.

4.4. Limitations of capacity building

While capacity building is a necessary component of adopting sustainable business practices and models in SMEs, it is not sufficient for many adoption processes. On the one hand, we have already highlighted the importance of additional support functions provided by the ecosystem such as conducive regulations, funding schemes, and training programs (cf. Forrester et al., 2023). On the other hand, adoption processes are substantially hindered by the lack of such support functions, or, even worse, by regulations, funding schemes and training programs that deliberately oppose or misdirect adoption efforts of sustainable business practices and models (various examples can be drawn from contemporary politics on federal and state levels in the U.S.). Thus, power dynamics and imbalances need to be considered and addressed when embarking on capacity building activities as the ones described above (cf. Smith et al., 2022; Wittmayer et al., 2024). This might include reframing the notion of capacity building in order to signify abstaining from one-directional undertakings and acknowledging the (colonial) history of imposing and forcing training and education on vulnerable and marginalized people (cf. Lezak, 2024).

5. Co-design, joint implementation, and formative evaluation of transformative sustainability experiments

5.1. Transformative sustainability experiments

A transformative sustainability experiment (TSE), conceptualized as a transdisciplinary research practice, is a governance approach for promoting sustainability (Frantzeskaki et al., 2018). TSEs creatively trial new ways of “organizing, doing, relating and, generating alternative (forms of) innovative solutions with the potential to address contemporary [urban] challenges” (Frantzeskaki et al., 2018). As a solution-orientated approach, experimentation enables joint learning, knowledge sharing and co-production (Lezak, 2024). TSEs can be seen as an “early take-off phase of transitions where these experiments find their place within new niches and aim to produce evidence about solutions to sustainability problems” (Caniglia et al., 2017). Furthermore, following Caniglia et al. (2017), TSEs are “Real-world Experiments” with participatory control, which aim to produce actionable knowledge (and evidence) (see e.g., Caniglia et al., 2021). Within the context of this study, TSEs are defined as

Purposeful interventions involving small- & medium-sized enterprises (SMEs) as active or leading actors with the aim to contribute to sustainability transformations beyond the SME, and in doing so, also addressing deep leverage points (Abson et al., 2017). Interventions are (i) co-designed between relevant “practitioners” and TRANSFORM researchers. This co-design includes among other things a clear definition of the specific research questions to be answered as well as defined sustainability outcomes aspired. Furthermore, interventions are (ii) embedded in a formative evaluation following a predefined evaluative scheme enabling individual case analysis and cross-case comparisons.

Actionable knowledge, or the learning capability of individuals to connect heterogeneous elements (i.e., political, social, economic, environmental, technological), emerges from the TSE process

(Antonacopoulou, 2006; Wiek et al., 2012). This knowledge often exists as actors’ implicit knowledge and is made explicit and useful through the collaborative research process (Wittmayer and Hölscher, 2018). This closely relates to absorptive capacities at the individual level, and at the organizational and inter-organizational levels where knowledge is gained or broadened.

5.2. Transdisciplinary co-design of new sustainability experiments

The desired outcomes of TRANSFORM experiments were both (i) contributions to transformations of crucial socio-ecological or socio-technical sub-systems aiming to mitigate major sustainability—especially ecological—crises as well as (ii) capacity building through the experimentation process. Even though more experiments were designed and implemented, in this paper we focus on 13 experiments realized that we evaluated for cross-case comparison. An overview of the experiments is presented in Table 3.

TRANSFORM TSEs concentrated on food system justice and sustainability, circular economy, or carbon neutrality and climate change (and, in some cases, the intersections among them). Several of the experiments concentrated on broader sustainability-promoting ambitions, targeting, e.g., the broader business ecosystem (e.g., multiple SMEs, organizations & agencies, production chains, resource systems) or University – SME collaboration, experimenting with single or multiple measures. A ‘leverage points’ view of experimentation (cf. Meadows, 2008) shaped the design of these interventions: targeting deeper underlying leverage points, such as values, worldviews, and relationships in addition to more familiar technical or efficiency-based features, enhances their transformative potential. Even so, was clear that all of the experiments carried out were not equally transformative, and the ultimate value of many of them will not be evident until well after the completion of the experiment.

5.3. Experiment entry points & amplification ambitions

All experiments had transformative practices or model implementation ambitions at their core. However, experimentation entry points and amplification ambitions differed. Three “systemic entry points” can be distinguished:

1. *Co-create*: Developing and implementing a transformative practice or business model in a concrete context and exploring how its positive impacts can be stabilized, sped up and/or increased
2. *Transfer & adapt*: Testing how existing practices or model implementation can be transferred to and/or adapted for other contexts outside the SME, or
3. *Enable & strengthen*: Exploration of how a supportive business ecosystem can be established and cultivated that fosters transformative practices/models.

These systemic starting points can be generally related to the amplification mechanisms defined by Lam et al. (2020): amplifying *within*; amplifying *out*; amplifying *beyond*. The first two dimensions can be used as an orientation for selection of experiments to realize a stratification that allows for cross case comparison.

The dimensions described above have provided broad orientation parameters that were important for the design of the respective TSEs. Following a transdisciplinary research approach, researchers were encouraged to identify and define experiments collaboratively with practice partners. However, the process of reaching the experiment idea varied, for instance, based on established relationships with collaborating SMEs, levels of knowledge and expertise by researchers and practice partners, and established capacities. Below are three main ways of how the TSE were conceived and how the experiment co-creation process took place:

Table 3

Overview of the 13 reported TSEs, including countries in which they took place (MEX: Mexico, GUA: Guatemala; CAN: Canada; SWE: Sweden; GER: Germany), and their thematic entry points.

Name of the experiment & Location	Short description	Thematic entry point
MEX 1	Water use/filtration experimentation to improve water management practices. It included actors from the Data Hub of the Tec University, the Water Centre of Tec University, a small Laundrette and an art student.	Carbon Neutrality and climate adaptation
MEX 2	The experiment builds on an ongoing idea of local researchers to develop a water filtration system in tequila production to comply with the regulation and safely discharge the water or reuse it into green areas of the farms for irrigation or gardens.	Business ecosystem
GUA 1	The carrying out policy analysis of regulation and developed a protocol for construction waste separation in construction sites. The experiment included CentraRSE (Business Social Responsibility Centre), Porta Hotels Chain and ITSA Construction Company.	Circular Economy
CAN 1	Focus on collaboration to improve flood resilience. The participants, consisting of Cambridge and Waterloo Region-based businesses (including developers, real-estate industry), municipal decision-makers, and insurance providers, increased their flood risk awareness and had an opportunity to come together to discuss how to enhance their flood resilience.	Carbon neutrality & climate adaptation
CAN 2	Development of a deep energy retrofit program for best practices for commercial/multi-residential buildings (not realized). The team planned to create an outreach strategy to promote the Durham Greener Buildings initiative and engage stakeholders through interviews and workshops to gather feedback. The relevant actors were the Durham Region and the Windfall Ecology Centre.	Circular economy
CAN 3	Experiment focused on increasing service offerings, support, and knowledge sharing for sustainability-oriented SMEs by the region.	Carbon neutrality & Climate adaptation
SWE 1	Concentrates on growing hops hydroponically in a greenhouse located on the backside of a craft brewery with the ambitions to offset imported hops and related transport emissions. Later growing trials focus on increasing hop growth rates via CO2 augmentation (see 4.5 for details)	Food system justice & sustainability
SWE 2	TSE focused on perennial grain (Kernza) production/growing for beer production as an alternative to conventional beer ingredients such as barley	Food system justice and sustainability
SWE 3	The aim of the experiment was to develop competencies around the indoor cultivation of mushrooms used for outside sales in the organization's restaurant operations	Food system justice and sustainability

Table 3 (continued)

Name of the experiment & Location	Short description	Thematic entry point
USA 1	The TSE focused on the development of a functioning 1-acre food forest, the creating the first worker-owner cooperative in Arizona	Business ecosystem
USA 2	The experiment developed a training program where participants acquired combined business and sustainability competencies including cooperation skills, collective decision making, how to develop sustainable products, ability to develop a business plan, the creation of a business strategy & vision, budget & marketing strategy creation, business site selection, and identifying finance options	Food system justice and sustainability
GER 1	The TSE focused on improving sustainable food offerings in university canteen via nudging interventions and novel communication strategies	Food system justice and sustainability
GER 2	Developed effective training structure that combine familiarizing employees with sustainability in a workshop format where participants to experience and experiment with sustainable actions, while developing a broader human-centered approach that aligns human resource management with sustainability efforts	Food system justice and sustainability

1. Researchers had a specific idea about intervention options they wanted to experiment with and approach SMEs (and intermediaries) to collaboratively develop the experiment.
2. A TSE is co-designed by practice partners and researchers (and/or intermediaries) collectively.
3. SMEs have developed an intervention option and collaboratively further developed the TSE with researchers (and/or other collaborators) via, e.g., an experimentation call.

5.4. Experiment evaluations

All experiments were documented using a standardized workbook, for cross-case analyses. The workbook is based on the generic case reporting scheme by [Bernert et al. \(2024\)](#) and structured according to the main evaluation dimensions (i) outputs, (ii) outcomes, (iii) inputs, (iv) processes (see e.g. [Lüderitz et al., 2017](#)). Core outcome categories exploring transformational potentials, for instance, were based on [O'Brien \(2018\)](#). In addition, TSE amplification strategies were based on [Lam et al. \(2020\)](#). The full workbook with a total of 43 questions can be found in the supplementary material. In all the cases the documentation was performed by the researcher most involved in the experiment *ex-post*. However, for the Swedish TSEs an *ex-ante*, *in-situ* and *ex-post* evaluations of the experiment took place with added insights from practice partners (e.g., SMEs).

5.5. Illustrative experiment: Hydroponic hop growing, Sweden

Hydroponic hop growing is one illustrative example from the TRANSFORM project experimentation process. The experiment was co-created by a SME (craft brewery) and Sweden hub TRANSFORM researchers and augmented with other actors at different stages of the experiment. Instead of the experiment being time-limited, it has undergone several developmental stages throughout the duration of the project. Initial TSE planning was co-created; however, the experiment

was largely driven and monitored by project researchers. The initial aim of the experiment was to test if hops for brewing could be produced at the brewery, year-round, in order decrease quantities of imported hops, decreasing environmental impacts associated with hop production and transport. The growing system was a small greenhouse attached to the back of the brewery containing a 24-bucket ebb and flow hydroponic system. Early growing trials consisted of comparisons between different hop varieties, and hydroponically grown hops and hops grown in soil (in boxes). Initial trials also explored the conditions needed to grow hops in the winter (See Fig. 4) in Sweden including lighting and heating requirements.

Once basic growing competencies were acquired, researchers and SME staff collaboratively turned experiment attention to the multiple aims of increasing hop plant growth rates and improving indoor air quality in the brewhouse. For these comparative trials, researchers and technical staff at the brewery built a system that pipes CO₂-rich air from the brewing process into one side of the now divided greenhouse. Hop plants benefit from the added CO₂ in increased growth rates; brewery employees benefit from the decreased CO₂ levels from, e.g., the canning process, beer fermentation and wort tank sterilization.

Experiment results have shown that knowledge and competency development around many aspects of the hydroponic growing process. Furthermore, the experimentation process, augmented with ongoing formal and informal capacity-building activities have led to several other sustainability-focused initiatives at the brewery (Ness and Wahl, 2022). Although there have been persistent pest managements challenges throughout the duration of the experiment in its many forms, researchers have demonstrated that it is possible to produce hops on location. However, amplification potentials are limited due to the sheer quantities of hops required in brewing operations, and the limitation of surface area for additional greenhouse construction at and around the brewery.

5.6. Key findings from experimentation

For a synthesis across the different experiments we aggregated the rich information of the workbooks according to the categories (i) Success factors, challenges and system implications (ii) transformational potential (outcome) (iii) transferability and scalability, (iv) outputs (to date) and (v) process and input., We then analyzed the aggregated information using the Thematic Analysis methodology outlined by Naeem et al. (2023). Following this approach, systematic inductive coding produced themes, which then led to the development of concepts. A theme is open-ended and lacks direct interpretation, as its' development "involves organizing codes into meaningful groups to identify patterns and relationships" (Naeem et al., 2023, p. 4). However, a concept builds on a theme through deeper analysis and understanding, as it "involves understanding and defining concepts emerging from the data" (Naeem et al., 2023, p. 4). Table 4 presents the concepts that emerge across the respective 13 TSEs. Further in-depth analysis, particularly focusing on



Fig. 4. Greenhouse during winter growing trials.

Table 4

Synthesis of conceptual findings from 13 transformative sustainability experiments.

Subject	Emerging findings
Success factors, challenges and system	Financial backing, prior expertise, and a strong organizational structure supported the success of SMEs. While their inverse, resource limitations, lack of expertise, and weak organizational support, contributed to failure in sustainable transformation. Financial incentives drive the adoption of sustainable practices, but long-term continuation depends on their economic viability.
Transformational potential (outcome)	Common transformational potential across SMEs includes increased resource efficiency and improved food security. The transformational potential of TSEs engages in social factors of improving education on sustainability and building on personal empowerment.
Transferability and scalability	Among SMEs, expansion and scaling are viewed as future-oriented, with expansion tied to increased production relative to each SME's specific outputs.
Outputs (to date)	Three forms of TSE knowledge emerged from the outputs. First, experiential knowledge surfaced through identifying challenges with TSE metrics, often tied to funding constraints. Second, practical knowledge was applied in real-world contexts, especially in areas like land and resource efficiency. Third, theoretical knowledge focused on competency-building tailored to the specific needs of individual SMEs. TSE outcomes strengthened social relations by developing trust and collaboration between actors, while also ensuring informed commitment through education and knowledge-sharing
Process and inputs	Collaborative and trust-building through procedural structure and relational dynamics acted as a foundation for operational success. SMEs employ structured methodologies designed to facilitate knowledge transfer as an output. Internal team coordination and development structured the innovation process, with clear task division and internal leadership driving sustainability-oriented experimentation and implementation.

the relation between input, process, contextual embedding and the transformation potential of the experiments are currently on the way and will be published in separate papers.

6. Building capacity through co-produced sustainability experiments – key insights for theory and practice

6.1. The relationship between capacity and sustainability experimentation at the ecosystem level

The transdisciplinary research process followed here generated three key insights into the nature of sustainability experimentation, and its connection to the deeper process of transformation.

First, capacity-building is a necessary pre-requisite for experimentation, but the types of capacity needed to spark and amplify transformative approaches to sustainability are quite different from those that support a simple technical or efficiency-focused outcome. Bringing a leverage points perspective (cf. Meadows, 2008; Abson et al., 2017) to bear on capacity-building reveals that while building the skills and competencies dimensions of absorptive capacity may target the more superficial leverage points (while also being appealingly straightforward), it is the inter-organizational links that begin to target the broader system of which the organization is a part. Indeed, the concept of absorptive capacity as it currently stands still fails to fully encompass the dimensions of purpose, identity and worldview that align with the deepest leverage points, and the greatest potential for system-wide

transformation. Our data showed that targeted and creative capacity-building becomes even more crucial if amplification, rather than a one-off and bounded experiment, is the goal. Ultimately, we found an iterative relationship between capacity and experimentation: capacity was built *through* experimentation, which then revealed potential capacity gaps or needs that could be remedied through iteration.

Second, organizations require an enabling business ecosystem to realize transformative sustainability goals. Initial TRANSFORM research indicates that the capacity needs, deficits, and barriers faced by SMEs are often at the business ecosystem and policy levels in addition to the individual/group and organizational levels. Examples include the lack of awareness of opportunities for a more circular economy in the construction industry, lack of uptake of regenerative agricultural practices among other farms, the need for new norms in a sector, insufficient financing and grants, and the need for ways to engage and motivate SMEs to undertake sustainability projects. Other examples include inconsistent policies between municipalities or limiting policies and regulations (i.e. food regulations). Thus, when attempting to adopt and maintain sustainable practices and business models, SMEs face barriers at the business ecosystem and policy levels.

Third, our transdisciplinary process illuminated challenges that are common to organizations at many other scales, and in a diversity of sectors. This reinforces, and adds empirical evidence in support of, the observation that sustainability is at least as much a human, political, and social challenge as it is a technical one (Burch and Di Bella, 2021). Values, for instance, emerged as central to success, at multiple scales and moments in the innovation process. Interviewees repeatedly raised the values and ambitions of the owner/founder during pathway mapping interviews, and values emerged again during capacity-building activities aimed at eliciting visions of a sustainable business ecosystem. When the pathway mapping methodology was adapted and used to create new, forward-looking, experiment designs, participant organizations often discussed values (of customers, employees, competitors, funders etc) as key potential enablers *and* barriers to success. These values often in fact rest at the ecosystem level – for instance in the case of financiers to who share the values of the sustainability-oriented company in need of funding, and with the community that might reinforce, legitimize, and stabilize the sustainable practice.

6.2. Transdisciplinary sustainability science and the co-production process

Transdisciplinary co-production allows for a delicate bi-directional flow of insights. From the firm, researchers learned about the values/worldviews underpinning the organization, power relations within the organization, the behavioural or organizational barriers/opportunities, the technical dimensions of the problem, and the ambitions behind the experiment (Bulten et al., 2021; Strumińska-Kutra and Scholl, 2022). Throughout the capacity-building and experimentation processes, researchers wove in systems thinking (emergence, uncertainty, interconnectedness), sustainability transformations (combined social and environmental benefit, non-linear change, deeper leverage points, etc.), and amplification (not simply accelerating, but deepening, transferring, etc.) (Lam et al., 2020). This flow back and forth between practitioners and researchers fundamentally shifts the shape of the experiment, and the capacity of the organization to undertake it (Ness and Wahl, 2022). This is a direct counterpoint to framing researchers as passive observers or objective, value-free analysts, instead as reflexive scientists empirically exploring a bi-directional flow of insight and the co-production of actionable knowledge (Wittmayer and Schöpke 2014). It also draws attention to the variety of roles that might be played by transdisciplinary researchers: as funding providers, champions, or project managers, for instance. The roles that TRANSFORM researchers played varied widely across experiments, raising interesting questions about how scholars might most effectively glean nuanced theoretical insights while also directly facilitating actions that lead to ecological and social benefit.

7. Conclusions and future directions

Private sector organizations, including small- and medium-sized enterprises, bring a unique set of skills and capacities to sustainability challenges. Innovations in this sector are often heralded as having the potential to ripple throughout markets but remain largely piecemeal and uncoordinated. Over the course of 7 years, the TRANSFORM team of researchers sought to more deeply understand the pathways that businesses follow as they develop and implement new sustainability innovations, but also to directly build capacity and facilitate the transdisciplinary co-production of new experiments in partnership with businesses.

To achieve these goals we developed, tested, and refined a multi-step, iterative procedure that mapped the evolution of sustainable business practices, deepened absorptive capacity (both at the intra- and inter-organizational levels), and fostered the co-creation of new sustainability experiments. In doing so, we gained valuable insights into the nature of sustainability transformations.

The pathway mapping exercises carried out with 42 organizations in Canada, Sweden, Germany, Australia, the United States, Mexico, and Guatemala brought to light the complex ecosystem of actors that influence the design and implementation of sustainable business practices and business models. Capacity-building activities brought diverse tools and procedures to bear on the challenging of not simply increasing knowledge or technical skills, but also enhancing the ability of organizations to collaborate, reflect, and learn. We found links between capacities - knowledge, skills and attitudes, for instance, underpinned organizational capacities such as business plans, shared decision-making, and trust-building through collaboration. As in the pathway mapping exercises, capacity-building activities revealed the strong influence of human factors (trust, leadership, and values) that opened the door to technical innovation, which challenges the conceptualization of progress on sustainability as a largely technical endeavour.

In direct response to the ecosystem insights gathered through the pathway mapping, some (but not all) experiments involved a group of actors, not just one. If we consider absorptive capacity to be an ecosystem feature (ie distributed among actors and the interstices between them, rather than residing solely within one organization), then experiments can serve as a mechanism for building this capacity; the experiment may compel the firm to bring others in, share knowledge, and co-produce the outcome.

Furthermore, designing transdisciplinary sustainability experiments with amplification in mind is a very different task than simply focusing on an isolated or bounded set of activities. We found that explicitly sharing various pathways to amplification (replicating, scaling up, transferring, deepening, etc.) with experimenting firms sparked creative ideas around how the innovation might be refined to target deeper leverage points (for instance by bringing art into what had initially been a purely technical exercise). Likewise, we highlight the value of viewing researchers not as passive observers nor as holders of value-free truth, but rather partners in knowledge co-creation.

Ultimately, we are left with several pressing questions for future research. Given the broader challenge of a rapidly changing climate, deepening biodiversity crisis, and increasing inequality, it is important to critically evaluate whether the innovations developed by firms such as the ones involved in TRANSFORM were, in fact, transformative. Longitudinal qualitative and quantitative work is needed to establish evidence for the ‘transformativeness’ of the practices that emerged here – but this work must also account for the subtle emergence of shifts in the ecosystem that cannot be tied back to one single cause.

Further questions remain surrounding the policy designs and governance approaches that might most effectively support transformative approaches to sustainability in the small business community. Past work illustrates that incentives and financial dimensions are only part of the equation (Westman et al., 2019) – businesses, and their leaders, are enmeshed in the broader social fabric, and shaped by values,

habits, and culture. Future work should engage meaningfully with the relational and collective dimensions of sustainability transformations, and the specific role that businesses play in an ecosystem of diverse actors.

CRedit authorship contribution statement

Arnim Wiek: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Sarah Burch:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Megan Farrelly:** Writing – original draft, Investigation, Conceptualization. **Jose DiBella:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Kes McCormick:** Writing – original draft, Conceptualization. **Daniel Lang:** Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Christopher Orr:** Writing – original draft, Methodology, Formal analysis. **Barry Ness:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of Competing Interest

This manuscript represents original work that is not being considered for publication, in whole or in part, by another journal. There are no real or perceived conflicts of interest.

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Data availability

The data that has been used is confidential.

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