https://doi.org/10.51196/srz.26.2

TRANSFORMING ENERGY SYSTEMS, TRANSFORMING SOCIAL SCIENCE: SOCIAL RESEARCHERS AND COLLECTIVE EXPERIMENTATION IN ACTION*

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/// 1. Introduction

The accelerating climate change and the coexistent biodiversity crisis are among the many recognised challenges stemming from human activity's impact on the atmospheric composition and terrestrial living conditions (Steffen et al. 2015). The response to the threats identified via the work of natural scientists is a call for urgent, globally coordinated efforts towards a deep sustainable transition (Schot & Kanger 2018; Huang & Zhai 2021;

* This research was supported by EEA Grants 2014–2021 via the National Centre for Research and Development, Poland, under the "Applied Research" Programme (grant no. PL-Applied Research-0043). The project was co-financed (15%) by the state budget of the Republic of Poland. The research was also supported by the National Science Centre, Poland (grant no. 2018/31/D/HS6/02972).

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Bińczyk 2024). Sustainable transition is most advanced within the energy sector, which is responsible for the majority of greenhouse gas (GHG) emissions. What is more, to meet the set objectives of GHG rapid reduction, similar transitions must soon extend to other industries, such as agriculture and construction (IPCC 2018: 17–18). The farmers' protests against the Green Deal and the Nature Restoration Law in numerous European countries in 2024 remind us how crucial it is to maintain social support for this policy direction (McLoughlin 2024). The complexity of this undertaking can be overwhelming as it entails the widespread and rapid introduction of novel technologies; their integration with existing infrastructures; accompanying lifestyle, behavioural, and business model changes; and winning and maintaining public support for these processes by creating benefits distributed fairly in highly diverse contexts.

As sustainable transition demands an unprecedented mobilisation of resources, it is worth asking how the skills and knowledge developed within the social sciences can serve as valuable assets in this process. We argue that such transition requires not only an integrative trans- and interdisciplinary approach (cf. Cherp et al. 2018) harnessing the explanatory and predictive power of different academic disciplines, but also the emergence and consolidation of new understanding of the social researchers' role in the process. To put light on that, we reflect on our experience from a specific research project aimed at supporting stakeholders in creating solutions that would foster enduring support for sustainable transition by aligning with local resources and needs. Inspired by the understanding of socio-technical change as a translation – and not, for instance, a diffusion of innovation – prevalent in actor–network theory (ANT), we propose to frame the dynamics of socio-technical change as a collective experimentation for sustainable transition (cf. Stasik 2024). That allows us to capture the necessity for simultaneous modification of attitudes, interests, institutions, and infrastructure in the process of developing sustainable solutions. We argue that the successful support of this processes necessitates a shift in both the understanding and performance of social research – as well as in the social institutions that enable this work. Translation will only be effective if it also engenders change within the sociological community itself. With that argument, we contribute to the rich and diverse discussion within the social sciences that has emerged to support sustainable transition processes (Loorbach et al. 2017). To acknowledge that, below, we shortly present the perspective of sustainable transition studies on the transition dynamics, introducing the notions of carbon lock-in and multi-level perspective.

In the following section, we provide a detailed account of the actions our team undertook within the "Green Heat" project, led by researchers from the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences and conducted in the city of Legionowo.[1] Our objective was to support the creation of local solutions for low-carbon heating. We reflect on how the involvement of social scientists can enhance this process of collective experimentation.

We start with the observation that the social scientists attempt to support sustainable transition processes in several ways. First, they develop theoretical models of change governance that account for the social dimensions of this process – unlike the necessary planning that focuses on the transformation of technological systems – thereby facilitating better planning and management of the transition process. Second, they assist stakeholders – from European policymakers to local informal groups campaigning for cleaner air – in developing specific solutions that have the potential to replace fossil fuel-based systems, with special attention paid to the social dimension of the process. Third, there is the potential to integrate these perspectives: theories and models developed by social sciences can support action-oriented stakeholders, and the knowledge gathered in this process, transformed by the effort of engaged social scientists, can help to further refine models of sustainable transition governance.

All these directions of action encourage the search for new approaches to scientific work and collaboration with societal partners. Those include incorporating the needs of stakeholders from the very beginning of the research process while leveraging the strengths of social sciences over, for instance, consultancy research – namely keeping its ability to generate knowledge applicable beyond the initial context, and subjecting developed models to transparent evaluation and discussion. The latter often relies on close collaboration with researchers from other fields, such as engineering or natural sciences. Scholars often refer to this mode as transdisciplinary or transformative research. Furthermore, considering the dynamics of expectations within the academia, both towards individual scholars and the institutions that employ them, transformative research must also be

[1] The "Green Heat – Towards Collaborative Local Decarbonization" project benefited from the Applied Research Programme grant from Iceland, Liechtenstein, and Norway through the EEA Grants. The project's aim was to contribute to the elimination of fossil fuel-fired boilers in Poland and to present feasible scenarios to decarbonise energy systems in Polish households. The project lasted from February 2021 to April 2024. This article adapts parts of the project's deliverables, both conceptual and empirical reports: Dembek et al. (2021, 2022), Dańkowska et al. (2024). The development of the concept presented in this article also received support via a grant of the National Science Centre, Poland (2018/31/D/HS6/02972).

excellent according to academic evaluation criteria – that is, publishable in top-tier journals and publishing houses. Thus, transition researchers face an extraordinary array of expectations: their work should contribute to mitigating global environmental crises by finding local solutions; it should be useful to partners from other scientific disciplines and, most importantly, from other sectors, such as local government or business; and its process and outcomes should yield insights important for the development of social theory.

We argue that a thorough discussion about field experiences in transformative social science is essential for properly embedding this concept and advancing this type of research practice. We are confident that reflection on our experience can provide a valuable reference for researchers planning similar interventions. We recognise that meeting the accumulated expectations of transformative social research may require structural changes in the organisation of research, as well as the creation of new identities and career paths for the researchers undertaking these efforts. Consequently, drawing upon both literature and our field experiences, we conclude with recommendations on how to effectively engage social science representatives in supporting collective experimentation for sustainable transition.

/// 2. Breaking the Carbon Lock-In and Transforming the Research Practice

Despite the strong scientific consensus on the necessity of conducting a sustainable energy transition, and the broad consensus among elites and political leaders as evidenced by the widespread rapport on the Paris Agreement,[2] the slow pace of changes is frustrating (e.g., Bińczyk 2018). On the one hand, due to the unique nature of the current transition – primarily aimed at mitigating the devastating external effects of fossil-fuel combustion rather than providing obvious benefits to users, such as lower prices or better functionalities (Grübler 2012) – a shared vision of the future and political support are essential conditions for its implementation (Kern & Rogge 2016). On the other hand, it is naive to believe that political will alone suffices to achieve this goal (Roberts et al. 2018). In this context, the social sciences offer a nuanced understanding of how attachment to fossil fuel-based solutions – sometimes referred to as carbon lock-in (Un-

[2] The renewed withdrawal of the United States from the Paris Agreement in January 2025 underscores how fragile such support can be – delving into the mechanisms driving this fragility is a crucial focus of social science research.

ruh 2000) – remains embedded in the foundations of the system, and what levers we can use to challenge this situation and pave the way for change.

Sustainable transition studies developed to support this radical change. The production and use of energy is one of the most important topics in the field of transition studies (cf. Klein & Coffey 2016; Ruggiero et al. 2018; Schreuer 2016). Initially, it drew from traditions of innovation studies, sociology of innovation, institutional theory, science and technology studies, management and organisational sciences, and selected strands of economics – particularly evolutionary economics. Over time, sociology and political science on the one hand, and studies on the dynamics of complex systems on the other, have become increasingly significant sources of inspiration (Loorbach et al. 2017: 612). The perspective of transition studies assumes that the answer to contemporary environmental problems – such as climate change and loss of biodiversity (cf. Steffen et al. 2015) – demands structural changes in the production and use of energy, food, and other goods and services (Geels 2011), accompanied and enabled by the change of regulations, values, lifestyles, and business models. Here, despite its radicalism, the demand of structural change does not considerably differ from the decade-old official recommendation of established international bodies such as the World Bank (2012).

Several features make sustainable transitions special in comparison with other, historical cases of innovation diffusion (Geels 2011). First, sustainable transitions are goal-oriented; the number of accepted policy targets, from the Paris Agreement, through Sustainable Development Goals, to decarbonisation targets agreed upon in RED II directives, demonstrates what it specifically means. That is, they display concrete objectives and a quantifiable indicator set to achieve by the collective efforts of different actors from the public, private, and civic sectors. Second, the innovations developed to tackle sustainability problems quite often fail to offer obvious benefits for the users, as their added value lies in minimising the externalities caused by the dominant socio-technological arrangements.[3] Third, the sectors that need sustainable transitions the most – such as energy or agri-food – are those where large and powerful companies dominate, which makes their involvement in the process of change both crucial and complicated. What is more, the transformation of large infrastructure is

[3] This is not to say that green innovations offer no benefits for the users – clean air after the replacement of fossil fuel-fired boilers is a great example. Indeed, their design should aim at offering such (co-)benefits. Still, the main reason to employ decarbonisation polices is to address the effect of fossil-fuel combustion on the climate, and some of the new solutions supposed to help in achieving this goal seem rather complicated to the users.

particularly difficult due to the longevity of material structures and the substantial techno-institutional interdependencies. Significant path dependencies lead to the regime's resistance to technological and institutional changes. Importantly, planning and decision procedures perpetuate these characteristics of the regime by neglecting radical system alternatives and focusing on limited value concerns (Truffer et al. 2010). As possibilities for change result from the interplay of incumbent actors' strategies and the actions of allies supporting decarbonisation, pathways to transition will clearly vary depending on the social, technological, and organisational context (Gui & MacGill 2018). This means that we cannot simply transfer technological solutions that enable energy transition in one context, because its success relies on a variety of local conditions.

One of the most influential perspectives in sustainable transition studies is the multi-level perspective (MLP), developed by Frank Geels, Johan Schot, and others. It focuses on the processes of structural change, investigating how emerging innovations struggle with existing socio-technical systems and what conditions they need to impact those systems. MLP relies on concepts from evolutionary economics, science and technology studies, structuration theory, and neo-institutional theory (Geels 2011: 26). It uses the framework of three levels: socio-technical landscape, socio-technical regime, and niche innovations. We should not understand these as ontologically different; instead, we may paraphrase ANT and say that "higher" levels are more stable as their basis includes multiple strong connections between various human and nonhuman actors: people, institutions, and pieces of infrastructure. These connections create lock-ins, which make it very difficult for new solutions to break through to the mainstream. Indeed, that is possible only if the socio-technical regime adjusts and transforms.

In MLP, breaking the stability of the regime requires pressure from the landscape – for example by changing international regulations, such as the emissions trading systems (ETS) – and simultaneous challenge by niche innovations. The latter emerge in relatively small networks of actors who support and invest in them based on a shared vision. However, pressure from the landscape often appears as the main cause of destabilisation; it can also stem from social or technical problems intrinsic to the regime, or from competition with emerging (niche) alternatives. What is more, pressure can be

> of economic nature (e.g. shrinking markets, changing markets, supply problems, competition from new entrants or new technologies, etc.), resulting in performance problems and decreasing financial

> resources, or of socio-political nature (e.g. changes in policy, public opinion, cultural discourse, social movement protests, etc.) affecting the legitimacy of the regime. (Di Lucia & Ericsson 2014: 12)

According to MLP, it may be helpful if the development of innovations occurs in protected spaces, without the necessity to directly compete with incumbent actors, who usually offer more mature and efficient solutions than products at the early stage of the innovation journey (Rosenberg 1976: 195). This observation leads to the focus on the interrelation of social and technological change: development in the niche is necessary not only to perfect technology but also to create new practices, meanings, and user routines. This, in turn, puts high hopes on the potential impact of experimental, pilot, and demonstration projects, which constitute an important phase between research and development (R&D) and market diffusion. Co-creation of innovation in the niches serves as a crucial resource for sustainable transition, and thus, it is one of the most important terms for organising the thinking about the mechanism of system transformation (Sengers et al. 2016).

Referring to this tradition, we propose the notion of "collective experimentation for sustainable transition" as a useful device which renders visible how overcoming the carbon lock-in by introducing new default solutions requires transformation in relationships within entire networks of cooperating actors and creation of new coordination mechanisms. This concept enables us to demonstrate how seeking appropriate responses to observed planetary crises leads to the simultaneous generation of knowledge, the introduction of technological innovations in the form of new devices, and the development of associated new identities, social practices, relationships, and rules. Inspired by the ANT tradition (Latour 2005), we see carbon lock-in as composed of heterogeneous elements, including humans, technologies, texts, institutions, and even natural phenomena. These elements are not predefined or stable but undergo constant shaping and reshaping through interactions. Thus, we stress that collective experimentation is inherently embedded in interactions with the elements of the existing regime, which shapes these innovations while they alter it too. That is, we highlight the understanding of (socio-technical) change as "translation." In the process of translation, diverse actors – both human and nonhuman – interact, negotiate, and influence each other, leading to the formation and transformation of networks. Through translation, these heterogeneous elements come together and align to form a network in a series of interconnected actions.

This process allows us to trace the relationship between experimentation and the material devices and institutions that constitute carbon lock-in: specifically, how actors in the experimentation process simultaneously utilise available resources, modify and expand possible courses of action, and contribute to changing the conditions for thinking, acting, and organising in the energy sector (see Wittmayer et al. 2022). We also emphasise that collective experimentation for transition requires broad engagement, and its success demands collaboration with the actors entrenched in the carbon lock-in.

Indeed, the necessity to engage with stakeholders in the creation of socio-technical innovations enjoys wide acknowledgement in the academia and among practitioners (Chilvers et al. 2018). Thanks to the early (upstream) stakeholder engagement, the innovation design accounts for different values and interests, which can be a key to its successful implementation. Two categories of stakeholders are essential: first, organised stakeholders such as policymakers, industry representatives, large nongovernmental organisations (NGOs), local authorities, or powerful social movements; and second, the "regular people" who are not particularly active as members of powerful institutions but have a stake in the problem the innovation is about to solve. We can understand the engagement with the first group as negotiation with the spokespeople of the current socio-technical regime, although – especially at later stages of the transition process – organised stakeholders may also promote the change. The engagement with powerful stakeholders reflects the basic challenge of sustainable transitions: the involvement of powerful actors in the process of change is crucial but causes many complications, as they often show more interest in diminishing change than its acceleration (Markard et al. 2020). Members of the second category include citizens, potential users, or members of local communities. In the energy sector specifically, the concepts of "energy citizenship" and "energy democracy" invite us to rethink the possible ways to engage energy users as more active stakeholders of the changing energy system who can support more progressive policies or oppose the change (Ryghaug et al. 2018; Wahlund & Palm 2022). Their involvement may bring crucial insights and contribute to the innovation's success, although it often proves difficult to meaningfully arrange.

The development of various forms of local cooperation for energy production, consumption, and trading, such as energy communities and energy clusters (Bauwens et al. 2022), may serve as an exemplary case of collective experimentation. On the one hand, it represents an iconic example of social innovation in the energy sector – solutions that create new

opportunities for action, forge new interests, groups, and identities, and may impact the pace and direction of the change (Sovacool et al. 2023). Simultaneously, it drives the search for new technological solutions and prompts the exploration of new operational methods for the power grid, such as enabling local energy and flexibility markets (Vernay et al. 2023). On the other hand, understanding the development of energy communities – and the ongoing challenges they face – requires acknowledging the extent to which their capabilities have inextricable links with their entrenchment in the institutions and infrastructure of the socio-technical regime at every stage of their existence (Ceglia et al. 2020; Stasik & Dańkowska 2023). Another example includes interventions conducted in the form of "living labs" or "city labs" (Hossain et al. 2019): their growing popularity results from the reflection on the significance of experimentation in the context of real-world challenges. These initiatives rely on the collaboration of various urban actors – including representatives of public administration and often involving social researchers – to develop and test new solutions for sustainable development before deciding on their broader implementation (see, e.g., Dembek et al. 2022).

Thus, the understanding that the adaptation of sustainable solutions requires transformation in relationships within entire networks of cooperating actors motivates us to account for the needs, interests, and practices of local stakeholders who are to live with it – and profit from it in the short and long term. Against this background, we analysed how the contribution of social scientists supported the collective experimentation on the zero-carbon solutions for heating systems in Legionowo.

/// 3. Site of Experimentation: Challenges of Heating System Transition and the "Green Heat" Project

3.1. Heating System in the Carbon Lock-In

The issue of modernisation and decarbonisation of the heating systems in Poland is both important and urgent. First, the primary source of heat remains coal combustion. In 2022, fossil fuels such as coal, gas, and heating oil generated 82% of the energy in collective heating systems, while only 12.6% of energy came from renewable sources. In individual heating systems, as much as 55.2% of households in Poland used district heating for their rooms. At the same time, 20.9% of households used hard coal for this purpose, 14.6% chose natural gas, and 20.9% opted for firewood. Only

0.69% of households used heat pumps, and 0.4% employed solar energy (GUS 2023). Additionally, over the past 20 years, CO_2 emissions from heating have only decreased by about 15.5%.

Heating is one of the main reasons of air pollution. Thirty-three out of the fifty most polluted cities in the European Union (EU) lie in Poland, which resulted in widespread anti-smog campaigns (Frankowski 2020). The EU's climate and energy targets, national laws, and local regulations have a significant impact on the decarbonisation process, serving as key stimuli for energy transformation development.

However, the decarbonisation of heating systems faces numerous challenges. With district heating predominantly sourced from fossil fuels, users have little agency in the transition to zero-emission alternatives, as this shift primarily depends on the actions of district heating providers – although public pressure can influence the pace of change. In contrast, households responsible for their own heating play a vital role in driving the transition, acting as both owners and investors. However, their engagement is contingent upon a variety of factors, encompassing attitudes and values concerning energy transition and climate change mitigation, as well as the perceived benefits and drawbacks of available alternatives. Specifically, the high initial costs of investments in energy efficiency and renewable energy technologies serve as a significant barrier for households. In this regard, it is essential to consider socio-material disparities among households and the issue of energy poverty (Sokołowski et al. 2023; Stojilovska et al. 2024). Many households currently see no alternative to their existing heating systems, such as gas, stating that renewable energy systems are still at the early stages of development. At the same time, when given a supportive context, the dependence on individual agency allows for potentially faster and more adaptable progress than the more centralised transformation of district heating. In this situation, existing subsidy programmes play a vital role but are often insufficient. Ensuring stability in the rules and regulations that underpin these programmes, along with information campaigns and organisational support in filling out relevant applications, is a crucial aspect. Russia's full-scale war against Ukraine, the resulting energy crisis and rising energy prices, and concerns over the instability of fossil-fuel supplies and their prices added a layer of uncertainty for engaged actors.

Thus, due to its complexity and importance, eliminating fossil fuel-fired boilers from Polish households, namely the goal to which "Green Heat" was to contribute, requires broad engagement in collective experimentation for sustainable transition.

3.2. "Green Heat": Experimentation Team to the Rescue

The "Green Heat" project assumed from its beginning that solutions – nonexistent when the project started – must emerge through experimentation. After coining the idea, the consortium gathered in the IdeaLab format,[4] an innovative way of generating research projects through intensive workshops involving scholars from various disciplines to address challenges on a specific topic. The format assumes building interdisciplinary teams with people unfamiliar beforehand, to develop intentionally bold and risky responses to socially relevant needs. These origins of the "Green Heat" project added to both its strengths and advantages, and to its limitations unfolding throughout the project's implementation.

The project assumed employing transdisciplinary knowledge to develop and exercise a participatory process of co-creating alternative heating solutions. Engaging stakeholders, both organised entities and "common residents," was both necessary and appropriate for the project's scope. The research team intended to participate in the process of multilayered change, combining its technical, organisational, and social aspects. Adequately, the project team consisted of engineers, social scientists, system scientists, economists, and education experts. They were to support the participatory process via cooperation, contributing to the co-creative effort. The interdisciplinarity of the research team put epistemological translation in the centre of the process.

Initially, acknowledging the challenges of interdisciplinary cooperation and the variety of interests among the stakeholders, the team assumed certain developments in Polish regulatory environment. Those expectations included the introduction of collaborative business models – such as energy communities, new to Polish law – within the project's lifespan, namely before 2023. By the end of the project, that still did not happen effectively. As a result, the pool of eligible business models for heating systems alternative to the coal- and gas-based ones remained quite limited. This limitation further conditioned – and corresponded with – a small variety of technical solutions to introduce; considering the scarce or nonexistent options for collective and/or communal scenarios, the most popular option was a simple, individual replacement of a carbon intensive heating source with a heat pump, often combined with photovoltaics (PV) installation

[4] The IdeaLab workshop "Cities for the Future: Services and Solutions," organised by the National Centre for Research and Development, took place on 2–6 March 2020 in Otwock, Poland (for details, see https://www.gov.pl/web/ncbr-en/idealab).

and retrofitting. Then, exploring the possibilities for more experimental scenarios via looking for less obvious solutions to the fossil-fuelled heating problem faced hindrance by a rapid increase of uncertainty caused by Russian full-scale invasion of Ukraine in 2022 and the resulting energy crises, economic turbulence, and inflation. That leads us to consider the limits of bottom-up experimentation and its dependency on both the national policies and changes in the broader environment. At the same time, the question about the role of social researchers in the process remains open for investigation.

/// 4. Collective Experimentation in the Field

Below, we outline the project stages where the involvement of the social sciences team was most significant. These stages include: (1) preparation for activities: dialogue with project participants about the importance of participation in planning the transformation and joint stakeholder mapping; (2) local diagnosis based on qualitative and quantitative data analysis; (3) workshops with residents; and (4) stakeholder consultations aimed at developing specific solutions. Their aim was to generate knowledge about the social expectations and readiness for action, and to mobilise different stakeholders to participate in the collective experimentation. We highlight the difficulties encountered during these stages, describe how we addressed them, and signal the broader insights for transformative research that one can draw from these challenges.

4.1. Preparation: Building Common Ground

Acknowledging the disciplinary diversity of the project members as both a strength and a challenge for the collaboration, the project assumed a face-to-face meeting that would last two days and allow for better understanding of how these diverse perspectives might feed the experimentation process. However, due to the COVID-19 pandemic and related restrictions, the project team could not meet in person for a long time. Instead, we organised a series of shorter online workshops hosted by the subsequent teams, intended to present their perspective and foster mutual understanding. Although that was the best solution in the described circumstances, we believe that a face-to-face workshop would have benefited the team more. The social sciences team presented the approach that identified the stakeholders' commitment to the new solution as the key condition for suc-

cess, no less important than business viability and technical feasibility. Attempting to translate this general rule into specific actions, we invited our partners to consider the role of different stakeholders in the tasks planned by subsequent teams – namely how their involvement might lead to better-quality outcomes, but also how they could profit from the project's actions.

In the following weeks, the social sciences team also led a workshop on the stakeholders' identification. Discussions in groups composed of the members of different teams allowed them to exchange knowledge and learn about each team's understanding of the decarbonisation challenge, derived from their disciplinary affiliations. For the social sciences team, the workshop provided better understanding of the project partners' knowledge needs related to local residents' readiness for actions.

Although these meetings fulfilled their initial goals, we believed that they should continue in the following years. To build the understanding of how different disciplines may contribute to collective experimentation is not a one-time event, but rather a process that should play an important role in the inter- and transdisciplinary project management.

4.2. Entering the Field: A Local Diagnosis

The initial diagnostic phase of the "Green Heat" project was a cornerstone in the participatory, iterative, and locally embedded process aimed at decarbonising residential heating systems in Legionowo. The study took place between September 2021 and June 2022. Its primary goals were to understand the residents' perceptions of energy transition and identify barriers and motivators for adopting renewable energy solutions. Specifically, the diagnosis sought to answer key questions regarding how the residents viewed the shift from fossil fuel-fired boilers, their readiness to invest in new renewable energy solutions, and their motivations and concerns surrounding this transition. This social diagnosis proceeded in a broader context where the project partners were simultaneously conducting a technical diagnosis via mapping the existing heat sources, infrastructure, and housing conditions in Legionowo, and analysing potential financial and business models to adopt in Legionowo. Through these combined actions, we intended to render visible the entanglement of the social, technological, and financial dimensions of a local transition.

To conduct a thorough diagnosis, we selected appropriate research methods and consulted them with project partners. This collaboration was crucial to align the research tools with the expectations and needs

of all project members. The research methods included document analysis, a representative survey of 500 households, and in-depth interviews with residents. Desk research involved reviewing existing documents to understand the air pollution situation in Legionowo, the city actions supporting the residents in transitioning from fossil fuel-fired boilers, and other relevant local conditions. The representative survey aimed to gauge the frequency and distribution of attitudes towards domestic heat sources and modernisation prospects. The survey included the following sections: household characteristics, such as building features or household composition; heating-related practices, attitudes, and opinions; knowledge and opinions on the environment and energy transition; and socio-demographic data of respondents. We conducted in-depth interviews with forty-seven residents – a diverse group with varying characteristics, including age, gender, heating source, and building type. At the first stage, we conducted eighteen semi-structured interviews with twenty-three interviewees – that is, thirteen individual interviews and five interviews with two respondents. The interview topics included: values regarding household heating; evaluation of the current heating system; attitudes towards replacing the heating source; views on collective community action; and opinions on climate change, air pollution, and energy policies at local, national, and European levels. Additionally, we conducted individual interviews with public housing residents: six interviews with residents using coal for heating, and eighteen interviews with users of heat pumps.

Having analysed the data, we presented them to the project team for discussion. This collaborative analysis was vital for aligning the project's subsequent phases with the diagnosed needs and attitudes of the residents.

However, during the diagnosis phase, several challenges emerged that influenced the project's trajectory. First, recruiting participants and encouraging discussions about heating systems proved difficult due to the perceived technical and mundane nature of the topic. Additionally, the COVID-19 pandemic imposed significant constraints, shifting a large part of interactions online and reducing the scale and scope of engagement activities. Also, due to the severe disturbances to almost every area of everyday life, residents and other stakeholders displayed less interest in the project's topic than initially expected. The alarming challenges of energy transition seemed to have given way to more urgent ones, namely health risks and economic crisis. Second, many residents were unfamiliar with or sceptical about new solutions like heat pumps or energy communities. The legal and economic frameworks for these solutions were only slowly evolving, adding

to the uncertainty. Furthermore, the project aimed to move away from fossil fuels, including natural gas, which the vast majority of residents viewed as an abstract and entirely unrealistic idea. The reason was the perceived harmlessness of natural gas as a heat source in terms of both air quality and climate change, as well as its popularity and lack of proven alternatives. Third, ensuring that the diagnostic results could inform practical interventions was a persistent challenge. We had to look for ways to make the results of the diagnosis actionable in terms of both project objectives, namely creating tailored solutions for the elimination of fossil-fuel boilers, and the process itself, namely effective communication and collaboration within the team and with external stakeholders. The fourth challenge was that of project planning and structure. We envisaged the diagnosis as the first stage of the project. The overall plan initially assumed that the diagnostic findings would remain consistent throughout project duration, providing a stable foundation for developing solutions. However, significant changes in external conditions emerged during the project, making timely adaptation crucial for achieving its objectives. In particular, the Russian invasion of Ukraine and the resulting crisis in fossil-fuel supply, as well as inflation and rising prices of energy created a situation of very high uncertainty, severely hindering the stakeholders' readiness to engage in experimental solutions and to undertake additional investments. The participatory and experimental character of the "Green Heat" project made it vulnerable to contextual changes.

In response to these challenges, we decided to adopt several strategies. First, to make the diagnostic results useful and adaptable, we employed a methodological tool of personas, commonly used in design and marketing (Hand et al. 2005; Nielsen 2012). Personas are fictional representations of user groups that capture their expectations, experiences, and behaviours (LeRouge et al. 2013). Based on cluster analysis of survey data (Zarańska 2015) and data from interviews, we created the following six personas: "Indifferent district heating user," "Community-engaged district heating user," "Stubborn coal proponent," "Stigmatised coal burner," "Distressed gas-boiler user," and "RES enthusiast." For example, the Indifferent district heating user views heating as a seamless service and is largely unaware of the energy source or costs, with limited interest in renewable energy. The Stubborn coal proponent values coal for its perceived independence and resists change, requiring proven technologies and stable financial benefits. Second, recognising the dynamic external conditions, we conducted a second survey two years after the first survey study – that is, in January

2024 – on the new random sample of 500 Legionowo residents to track changes in the residents' attitudes and understand how external turbulences affected their views.

Based on our experiences, we offer the following recommendations for similar transdisciplinary and experimental projects. First of all, personas or other tools and methods used in more practice-oriented fields, such as user experience, design, or marketing, can effectively translate social diagnosis results into actionable insights (Dańkowska et al. 2025). These tools facilitate communication with project partners and external stakeholders, including local authorities and residents, and support joint decision-making. Second, project design should demonstrate flexibility to accommodate significant external changes. Regularly updating the diagnostic understanding and remaining responsive to new developments can enhance project resilience and relevance. Moreover, ongoing consultations with project partners and stakeholders are essential for aligning research activities with practical needs and expectations, ensuring that solutions have roots in the lived realities of the target community.

Finally, we should consider the prediction that the near future is unlikely to allow us to avert crises similar to those experienced during the project (Homer-Dixon et al. 2021; Hening & Knight 2023; Hausner & Krzykawski 2023). The task of social researchers and representatives of other sciences responsible for project planning is to attempt to design the process in such a way that it creates clear incentives for participation even during times of turmoil and uncertainty. For inspiration, let us recall that some groundbreaking social innovations – such as the development of the cooperative movement – emerged precisely in response to crises that individual actions could not address. To this end, it is important to strengthen the focus on creating direct benefits for potential users of new solutions, including enhancing their resilience – the ability to cope with current and future shocks. This, however, necessitates a significant expansion of the social researchers' role beyond the traditional remit of data collection and even beyond facilitating dialogue and promoting sustainable development education. Successfully fulfilling this expanded role requires both additional resources and a transformation of researchers' professional identities.

4.3. To Have a Say: Citizen Workshops

We conducted four workshops with the residents of Legionowo to involve the community in the transition to decarbonised residential heating sys-

tems. These workshops, held between November 2021 and May 2022, were largely remote due to COVID-19 restrictions, with one in-person meeting at a municipal public library. Participant numbers ranged from seven to fifteen per session. The workshops aimed to present the project and its objectives, understand the residents' values and perceptions, inform them about potential solutions, and gather feedback on technical and business preliminary solutions.

In the first workshop, we introduced the project and facilitated discussions on local heating issues, different heating sources, and the future of Legionowo in terms of climate change and air quality. The second workshop aimed to discuss technological solutions that one could consider in the residential heating system's decarbonisation in Legionowo. To present these preliminary solutions and discuss them with the residents, we prepared three graphics with the technical project partners, illustrating different models: (1) domestic heat production and neighbourhood energy storage; (2) district heating and cooling microgrids; (3) a district heating plant expanding district heating networks based on renewable energy sources (RES). The meeting agenda included a presentation, followed by a discussion among participants to gather their opinions on the feasibility of these models in Legionowo.

The third workshop covered various government subsidy programmes for heating source replacement, like "Clean Air," "Stop Smog," or "My Electricity," as well as municipal initiatives. The final workshop explored factors influencing the low-carbon energy transition, including existing funding programmes, the impact of the Russian invasion of Ukraine, rising energy prices, and legal constraints.

The key conclusions from the workshops included the residents' concerns about poor air quality in Legionowo, the slow pace of fossil fuel-fired boiler replacement, some interest in but also scepticism about cooperation-based business models – for example due to preferences for owning heating systems – and the significant role of city authorities in initiating new solutions. The participants also highlighted the need for clearer rules in existing funding programmes, a consultation point in the city, and information campaigns on funding opportunities. Inflation, legal changes, and the unstable international situation due to the Russian invasion of Ukraine acted as challenges for planning heating source replacements.

The citizen workshops also faced several challenges. Conducting remote workshops due to COVID-19 restrictions posed difficulties in engaging participants. Recruiting the residents was challenging, and it was hard to

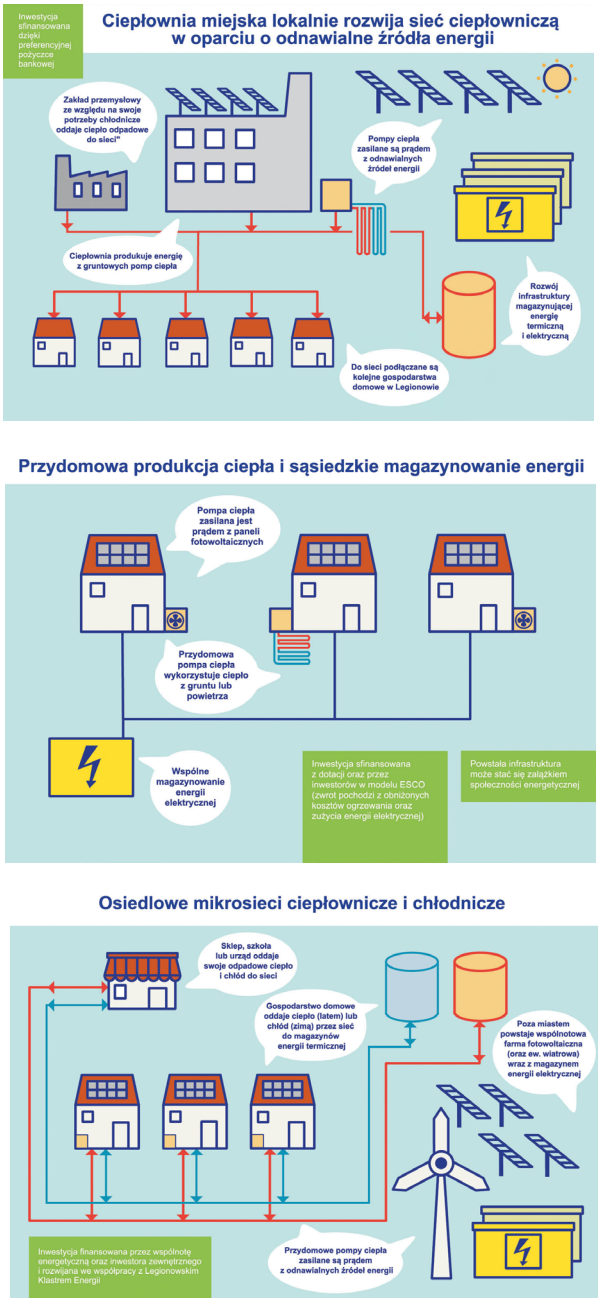

Figure 1. Three graphics illustrating preliminary technical and business models considered in the "Green Heat" pilot project in Legionowo: (1) domestic heat production and neighbourhood energy storage; (2) district heating and cooling microgrids; (3) a district heating plant expanding district heating networks based on RES.

Source: "Green Heat" research project materials, developed by the research team and presented during workshops with residents.

explain the benefits of early participation. Additionally, the three graphics illustrating different technical and business models proved too abstract and difficult for participants to understand, as these solutions were either non-existent or uncommon in Poland. Also, the proposed draft solutions lacked the detail needed for full comprehension by the residents along with the concrete benefits the residents could derive from them, particularly financially.

To address these challenges, we encouraged participation by offering various incentives, such as gadgets, shopping coupons, information on funding opportunities for heating source replacement or thermal modernisation, and technical analyses for buildings or apartments by the technical project partners. We used online group activity tools and leveraged the residents' contacts to invite others to participate. Dedicated posters and leaflets were created, and we utilised city communication channels and collaborated with local organisations to spread information about the workshops. We also engaged the residents at public city events, like NGO fairs.

Based on our experiences, we offer the following recommendations. In transdisciplinary projects, technical and business partners might expect clear guidelines on residents' needs and preferences to shape appropriate technological solutions and business models. However, our experience reveals that, particularly in the energy sector, residents struggle to engage in co-creation early in the process due to a lack of interest, knowledge, or motivation. This underscores the need to rethink the "energy citizen" model. Our experience indicates that it is crucial to acknowledge the limitations that hinder early resident engagement when there are no concrete solutions for residents to discuss, consider, and understand – including the understanding of tangible benefits for end users. In this perspective, social scientists play a pivotal role in enhancing residents' interest, knowledge, and motivation within the context of evolving external conditions and emerging opportunities. Crucially, effective participatory processes depend on tapping into existing social networks, where building partnerships with local organisations is essential for facilitating resident engagement. Collaborations with local environmental groups, smog alerts, or community leaders are key. Given the constraints of time and resources in research projects, building resident engagement from scratch is nearly impossible. Thus, leveraging established community relationships and social capital is paramount for successful citizen participation. Importantly, the timing of resident involvement influences the relationship between social and technical partners. Early engagement in social co-creation is essential to prevent it from becoming a mere formality, thereby ensuring a more balanced collaborative process.

4.4. Constructing Future Options: Consultations with Institutional Stakeholders

The "Green Heat" project team conducted stakeholder consultations involving the Legionowo City Hall, municipal companies, financing institutions, energy firms, and other entities, such as the Mazovian Energy Agency. Stakeholders discussed the project's objectives, identified collaborative opportunities, and showed interest in project-developed solutions. In particular, the team conducted consultations on potential solutions with representatives of the Legionowo City Hall and municipal companies to receive feedback from institutions central to the development and implementation of the suggested ideas. For instance, "Green Heat" proposed a universal mapping method allowing municipalities to identify buildings with high heat consumption, eligible for various funding schemes. In response, the City Hall emphasised the need for clarity regarding housing communities eligible for district heating network connection and funding utilisation. However, diverse heat sources in multifamily buildings pose a challenge, as they qualify for varying subsidy schemes. Consultations with municipal companies highlighted proposals like capturing waste heat from municipal sewage systems, with interest shown both by the Water and Sewage Company and the Heating Energy Company, albeit facing technical challenges. Other options discussed included expanding district heating based on RES, developing microgrids, and transitioning district heating away from fossil fuels, among others.

The "Green Heat" consortium further engaged in multiple stakeholder consultations to identify solutions for decarbonising the Legionowo residential heating system, focusing on two primary models. For instance, the model for the residential blocks on Daliowa Street aimed to replace existing gas boilers with ground-source heat pumps and PV panels. The key stakeholders included housing communities, municipal authorities, and private companies. Initial meetings with the Municipal Budgetary Authority and the Legionowo City Hall identified specific buildings for the pilot, with detailed discussions on technical and financial aspects. Subsequent meetings with private drilling companies and heat pump manufacturers addressed potential technical and social challenges. A site visit further facilitated practical planning. The following stakeholder consultations, including financial assessments and expressions of interest from several private companies, refined the project's scope. The Legionowo vice mayor and the Heating Energy Company president showed strong support, considering

funding options through the "PFR for Local Authorities" programme. Finally, the project team met with representatives of four housing communities on Daliowa Street, the Legionowo City Hall, a private energy company, and the Municipal Budgetary Authority. They discussed four transition scenarios, highlighting available nonrefundable funds, and recommended a scenario ensuring complete elimination of local GHG emissions.

Based on our experiences, we have identified several challenges for social scientists when conducting consultations with external partners in decarbonising residential heating systems. Successful consultations require the involvement of technical partners who can provide detailed explanations of proposed solutions. Social scientists can support these initiatives by highlighting additional factors, such as citizens' viewpoints; however, they are not in a position to lead these consultations independently. Moreover, our experiences show that long-term stakeholder engagement relies on existing institutions, such as cooperatives, organisations, and local governments, which will assume ownership of the implemented solutions once the project concludes and researchers depart. This partnership is crucial for the long-term sustainability of the proposed initiatives. Social scientists may play a unique role in facilitating consultations with technical partners and local institutions. They act as catalysts, initiating discussions and emphasising the importance of incorporating residents' perspectives into the solutions. However, one must remember that local actors – namely town administration and local utilities – are the ultimate decision-makers, especially after the project's conclusion. Finally, the success of social scientists' efforts is more pronounced in areas with a dense network of intermediary institutions that have close contact with residents. As already mentioned, the favourable result of low-carbon energy transitions depends significantly on local communities' social capital, which social scientists can help build and strengthen. Their actions are most effective when they leverage and enhance the existing social resources, ensuring that local entities are prepared to carry forward the proposed initiatives.

/// 5. Transforming the Collective, Transforming the Research Practice: Reflections for the Future

While the "Green Heat" project concluded, the need for sustainable transition – in Legionowo and beyond – did not, and neither did our commitment for the fostering of locally entrenched sustainable solutions. We remain convinced that engagement of local actors supports the emergence

of locally relevant benefits, and thus allows for the creation of stable social support for the solutions that caused it. If collective experimentation shows its full potential when co-created by the variety of concerned actors, the contribution of social scientists may lead to the inclusion of different perspectives that would remain unnoticed without this effort. "Green Heat" fulfilled this very goal, namely stakeholders' identification, local diagnosis, workshops, and consultations. At the same time, the overall aim of creating new solutions – based on the new business model and technological solutions – was only partly successful. Here, the strength of carbon lock-in – which manifested itself in regulatory obstacles and the support for the coal-based heating systems in the time of crisis through subsidies for households using coal to heat their houses – offered no space for the development of technologically feasible, business-viable, and socially acceptable new solutions, although the experimentation on Daliowa Street reopens this perspective. At the same time, our experience allowed us to revise some of our expectations related to the dynamics of engagement. Thus, when planning future projects oriented towards fostering collective experimentation, we will pay close attention to the following aspects.

First, to strengthen the potential of collective experimentation, one should devote even more time and effort to interconnect the findings on the social and technological dimensions of the process and the methods that produce them. Indeed, representatives of all disciplines have their habits on how to plan and carry out the research, which also secure the quality and the approval of colleagues, as in the peer-review process. Similarly to all other aspects of carbon lock-in, this one stabilises the system and ensures its efficient functioning but may restrain the necessary change. Thus, the question of how our research activities may evolve after considering new aspects of the process – to yield better and more relevant outcomes – refuses easy generation and execution, demanding a continuous effort instead. Social scientists, especially those trained in science and technology studies, may be prepared better than other partners to facilitate these processes. Here, we see the further transformation of the very methodological principles of different disciplines as a necessary part of collective experimentation – as discussed for more than two decades by proponents of postnormal science (Funtowicz & Ravetz 1993; Healy 2011).

The second recommendation stems from the reflection on the expectations towards representatives of social scientists expressed by project partners and institutional stakeholders – namely that we will be able to present what *the society* wants. Here, we should stress that the local public opinion

towards the issue at stake needs not only discovering, but also creation through the project actions. In the "Green Heat" project, we summarised the results of our diagnosis using personas to present the residents not only as they were at the moment of research, but also as relatively ready to change while the circumstances evolve. Similarly, the presentation of graphics of different future solutions aimed to build an attitude which remained absent before the project started. We believe that the goal of encouraging meaningful engagement in transition demands even more methodological experiments, particularly those that promote dialogue between disciplines and between stakeholders. Simultaneously, we must be aware of and reflect upon the values of traditionally conducted research – both in social and other sciences – which may weaken or become lost in this process. This requires a balance between striving for effective communication facilitating joint action and the rigour and precision guaranteed by established scientific methodology.

At the same time, our attempts to build the residents' engagement in the discussion on the heating system transition gave us a lesson of humility. Notwithstanding the obstacles – from COVID-19 restrictions to the Russian invasion of Ukraine – we discovered that the task of building engagement around the issue of heating transition as part of the project tasks is very difficult and demands resources, such as time, that researchers usually cannot commit. In this situation, we acknowledge that one should strive to build meaningful engagement not from scratch but through partnership with the preexisting social groups and network. However, in many places in Poland these groups are too weak to lead the effort. This reveals an important barrier to the upstream participation of common residents in the experimentation process. Contrary to some models of individuals described as "energy citizens," most residents must see the tangible benefit to engage in a discussion on sustainable solutions.

This observation leads us to the fourth point. Accepting the pragmatic attitude of the majority of local public, which only strengthens in the time of crisis, a project aimed at the creation of sustainable solutions should prioritise delivery of understandable benefits for users in the short and medium timespan. This attitude does not close the possibilities of creating important social innovations, but it accepts the fact that the vast majority of participating individuals perceives environmental benefits as interesting additions, not as the main motivator. Furthermore, we observed that the experience of crisis and uncertainty demotivated parties to engage with the project. Thus, acknowledging the turbulent time and

reality of polycrisis, we must learn to design the process in such a way that it appears as a solution in the turbulent time, not as additional burden. This instance, however, expects researchers to act as "community organisers," which demands a distinct set of knowledge, skills, and predispositions. Since combining these diverse roles is exceptionally difficult, the formation of multidisciplinary teams offers a promising approach. We should implement this strategy with the awareness that it will inevitably lead to new challenges, such as ensuring goal alignment among collaborators with varying backgrounds.

Finally, understanding the social dynamics of the transition processes contributed by social scientists allows for translating the results of collective experimentation between different arenas and levels. We can amplify the impact of local effort if we find effective ways to show decision-makers how they can use experimentation results to achieve goals that are important for them, as well as ways to help them understand how the conditions they shape impact – and impede – the potential of most ambitious local actions. We can also support peer-to-peer learning between local stakeholders, from local governments to NGOs and business innovators: here, the coordination of the efforts with technological partners is key, as the interested parties are ready to hear about social aspects of the process only if we present it as entanglement with technological transformation.

All of these actions – spending resources on fostering deeper understanding between project partners and discovering the transformative potential of collaboration for the very disciplines we come from; searching for methodological innovations that show society in the context of intended actions; building meaningful partnerships with local organisations; searching for modes of engagement that appear as solution to the crisis; and communication of the importance of the experimentation to the decision-makers and peer organisations – transcend the traditional list of social researchers' tasks. Many of these actions are time-consuming and require specific skills and attitudes which differ from the analytical skills mastered by scientists during their long training. What is more, engagement in these actions will not necessarily gain recognition during the evaluation of both researchers and the institutions that hire them. In conclusion, to build the critical mass of experiences and skills necessary to amplify our impact, we need to create more institutional support for such experimentation in the social science itself – which adds to the list of recommendations.

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/// Abstract

The accelerating climate change and biodiversity crisis necessitate an unprecedented mobilisation of resources for a sustainable transition. This article explores how the anticipated contribution of social science to this transition requires a redefinition of social researchers' roles. Drawing on sustainable transition studies, actor–network theory's concept of translation, and insights from a transdisciplinary research project supporting stakeholder-driven solutions, we offer recommendations for researchers engaged in similar endeavours. We demonstrate how the need for simultaneous modifications of attitudes, interests, institutions, and infrastructure within sustainable solutions also applies to the organisation of scientific research itself.

Keywords:
sustainable transition, collective experimentation, transdisciplinary research, transformative research, energy transition

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