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Energy justice intermediaries: Living Labs in the low-carbon transformation

Stefan Bouzarovski[a], Dimitris Damigos[b], Zoltan Kmetty[c,d], Neil Simcock[e], Caitlin Robinson[f], Majd Jayyousi[a] and Ami Crowther[a]

[a]Department of Geography, University of Manchester, Manchester, UK; [b]School of Mining and Metallurgical Engineering, National Technical University of Athens, Zografou, Greece; [c]CSS-Recens Research Group, Centre for Social Sciences, Budapest, Hungary; [d]Ariosz Ltd, Budapest, Hungary; [e]School of Biological Sciences, Liverpool John Moores University, Liverpool, UK; [f]School of Geographical Sciences, University of Bristol, Bristol, UK

ABSTRACT
This paper foregrounds the use of “Living Labs” as instruments for the delivery of just low carbon transformations. Living Labs are commonly understood as stakeholder-centred, iterative and open-innovation ecosystems that involve multiple forms of co-creation and engagement among different actors in a given territory. Over a period of three years, thanks to a unique pan-European action research study, three such Labs were set up in different locations in Europe – a large North-western European city (Manchester, England), a mid-sized mountainous town in South-eastern Europe (Metsovo, Greece) and a series of rural settlements in Central Europe (Nyírbátor, Hungary). Working closely with local residents and relevant organisational stakeholders, the research teams that led the Labs undertook multiple low-carbon interventions in the homes of low-income residents, while continuously monitoring the broader impacts of intermediation practices on energy equity and sustainability across three consecutive cycles of activity. We present and discuss the results of these activities, so as to uncover the impacts of Living Labs on energy poverty both before and during the Covid-19 pandemic.

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KEYWORDS
Living Labs; energy poverty; experimentation; transitions; energy justice

Introduction

Living Labs (LLs) are increasingly recognised as effective platforms for promoting environmental sustainability via knowledge exchange, engagement, innovation and collaboration. There is now a significant body of academic scholarship on the governance mechanisms and socio-technical practices that underpin the establishment and operation of these multi-stakeholder frameworks (Compagnucci et al. 2021). However, their application in the domains of social equity and inclusion has been less prominent. In response to this gap in research and knowledge, we ask whether LLs act as socio-technical intermediaries (Barnes 2019; Hiteva 2017; Kivimaa et al. 2019) towards the achievement of social justice objectives in the energy domain, in addition to delivering innovation in low-carbon transformations. In particular, we seek to examine the conditions under which LLs can help address energy poverty – a condition characterised by the inability to secure needed levels of energy in the home (Bouzarovski and Petrova 2015). We explore the linkages between LL interventions and

CONTACT Stefan Bouzarovski stefan.bouzarovski@manchester.ac.uk Department of Geography, Arthur Lewis Building, University of Manchester, Oxford Road, M13 9PL, Manchester, UK

the different structural determinants of energy poverty – particularly social exclusion, housing quality, energy efficiency and affordability. We also scrutinise how practices of intermediation within LLs interact with the wider systemic drivers of energy injustice, in terms of geographic characteristics, political dynamics and embedded infrastructural inequalities.

The paper explores the activities and results of three LLs that operated between 2018 and 2021 at three locations in Europe: a large Western European city (Manchester, England), a mid-sized mountainous town in Southeastern Europe (Metsovo, Greece) and a series of rural settlements in Central Europe (centring on Nyírbátor, Hungary). In their entirety, the Labs involved working with approximately 20,000 people, and the data in the paper is based on surveys, focus groups and interviews with over 1620 households. The Labs themselves were uniquely set up to focus on both environmental and social improvements, speaking to the conceptually and politically pressing challenge of just energy transitions. The Lab methodologies are described in detail in a series of data analysis reports (Bouzarovski et al. 2021; Damigos, Papada, et al. 2021; Kmetty 2021); each Lab followed a distinctive approach within a broad methodological and conceptual frame. Data collection methods were standardised to a higher degree when it came to the implementation of a customised online questionnaire survey, involving a total of 459 households across all three LLs, to explore the impacts of the Covid-19 pandemic on energy poverty.

Aside from this introduction, the paper consists of five sections. We first outline the key concepts that informed our analytical framing, focusing on the interface between LL approaches, on the one hand, and efforts to promote low-carbon futures and energy equity, on the other. The paper then interrogates the constituent elements and practices of the three LLs, examining the techniques they used in delivering their objectives, the challenges they faced in the iterative process, and the extent to which they were able to ameliorate energy poverty. We then move on to discuss the impacts of the Covid-19 pandemic on both energy poverty patterns and the uptake of low-carbon energy in the LLs. The subsequent discussion and conclusion section return to the research questions that we pose above, to unpack the practices of intermediation that underpin equitable decarbonisation.

Key concepts: Living Labs, sustainability transformations and energy poverty

LL approaches are socio-technically and politically heterodox in their essence. Even if there is a decidedly Eurocentric bias to both the academic literature and policy praxis on this topic, relevant contributions nevertheless recognise that LLs are fundamentally predicated upon variegated actors and motivations. Their heterogeneity is one of the reasons why LLs are defined and understood in diverse ways. A common thread running through much of the literature on the topic is that LLs tend to have clear spatial boundaries, while involving shared and open-ended forms of innovation to test new systems, products, services and procedures. From a social and material perspective, LLs require the introduction of a mix of technical infrastructures and installations, a well-functioning network of relevant actors, participation dynamics that are open to innovation, design approaches that are human-centric, as well as the involvement of local communities and users in their everyday environments. In this sense, Hossain, Leminen, and Westerlund (2019, 979) argue that there is a difference between what they term the "North American approach" in which LLs are considered "as demo-homes, home labs, or houses of the future" on the one hand, versus the European one, on the other, where the emphasis is on the development of platforms "to study users' everyday habits" (Hossain, Leminen, and Westerlund 2019). Nevertheless, as argued by Paskaleva and Cooper (2021), the operational dynamics, benefits and results of LLs are poorly understood and relatively inconclusive due to the lack of systematic research and fine-grained evidence.

In response to the fragmentation of state services, and requirements for innovations in environmental policy, public engagement and technological solutions, new modes of experimental governance and socio-technical intermediation are now at the forefront of urban climate action (Matschoss and Repo 2018; Pesch, Spekkink, and Quist 2019). Sustainability experiments evoke "attractive notions of innovation and creativity" (Evans, Karvonen, and Raven 2016, 1) by enabling technological and social transformations to be articulated in protected spaces and in real-world settings (Luederitz et al. 2017). Their outcomes operate within urban settings that are sensitive to institutional, economic and historical conditions, thus promoting the production of place-specific solutions (Barnes 2019; Hansen and Coenen 2015). Experiments are also seen as spaces for enhanced public engagement via community-led, grassroots action; this can both provide legitimacy to, and foreground the voices of, actors that are usually excluded from formal governance processes (Karvonen and van Heur 2014; Seyfang and Haxeltine 2012). It follows, therefore, that LL experimentation can facilitate participatory governance within novel political spaces outside of the control of incumbent political systems (Hoffmann 2011; Sharp et al. 2022). However, existing conceptualizations of sustainability transformations, intermediation and experimentation point to the deeply politicised and inherently contested nature of efforts to negotiate sustainable visions (Bouzarovski and Haarstad 2019; Gandy 2000; Rutherford and Coutard 2014).

There is extensive evidence to suggest that practices of experimentation, LL implementation – and sustainability transformations more broadly – interact with systemic injustices at multiple levels, while extending into the material realities of everyday life (Grandin et al. 2018). Compounding these contingencies is the fact that disadvantaged groups are likely to be disproportionally affected by the consequences of climate change due to the overlap between varied forms of vulnerability arising from urban inequalities and poverty, on the one hand, and the impacts of global heating, on the other (Banks, Roy, and Hulme 2011; Benevolenza and DeRigne 2019). Even if most forms of distributional injustice materialise at the endpoints of transition pathways and interventions, these inequalities are also reflective of the wider procedural and recognition injustices stemming from the political negotiation of low-carbon initiatives, as well as associated practices of decision-making and public discourse (Meadowcroft 2011). Consequently, the environmental governance of sustainable transformations and experiments deployed along the pathways towards the realisation of a given vision can generate deleterious outcomes built on utopian promises (Caprotti and Cowley 2016). The contestation, steering and mediation of low-carbon futures are all deeply embedded in infrastructures (Bulkeley, Broto, and Maassen 2014), all of which ultimately leads to the generation of new, and replication of existing, spatial injustices (Martiskainen et al. 2021; Sovacool et al. 2019).

Even if specific research on the relationship between experimentation and LLs, on the one hand, and energy injustices and energy poverty, on the other, is relatively rare, there is evidence to suggest that low-carbon interventions can generate new forms of inequality. For instance, Forster, Hodgson, and Bailey (2019) emphasize how the installation of low-carbon heating systems by local authorities in the UK resulted in higher energy bills and pushed members of ethnic minority communities into domestic energy deprivation. While widely adopted methodologies to tackle energy poverty in such cases rely on the provision of energy advice (Ambrosio-Albala et al. 2020; Fischer et al. 2014; Ramsden 2020; Reeves 2016), the possibilities and choices awarded to actors are limited by the wider systems of governance. Another widely accepted issue in context of energy poverty centres on rules that guide the interactions between energy consumers and the wider systems of energy provision (Lorenc et al. 2013). Building on the concept of material politics by Marres (2013), Martiskainen, Heiskanen, and Speciale (2018) demonstrate how engagement with a local community-led energy advice network enabled individuals seeking energy advice to participate in wider discourses around climate change issues.

Findings from the EU funded ENERGISE project (Sahakian et al. 2021) are pointing to some of the ways in which community stakeholders and intermediaries can be mobilised towards the achievement of low-carbon energy objectives in a LL context. Nevertheless, in this and related research on energy poverty and sustainability transformations (Damigos, Kaliampakou, et al. 2021; Longo et al. 2020), there is a discernible gap in knowledge in terms of how social, demographic, economic and structural factors (e.g. a household's financial situation, quality of housing, disability, gender, ethnicity) interact with low-carbon interventions. In particular, there is a need to integrate energy justice considerations (Carley and Konisky 2020; Jenkins et al. 2016) in relation to the distribution of benefits and burdens, and different forms of public engagement associated with sustainability experimentation processes. In order to address such lacunae in research and practice, the LLs analysed in the three sections that follow sought to address both innovations in the delivery of environmental policies and technologies, as well as transformations in the domains of social policy and poverty.

The Manchester LL

The Urban LL was based in Greater Manchester (GM), a metropolitan region in North-West England with a population of approximately 2.7 million people. This makes it the third largest metropolitan area in the UK, after London and Birmingham. The region is governed by the Greater Manchester Combined Authority (GMCA), which combines a directly elected mayor and political leaders from each of the ten metropolitan borough councils. The LL itself was principally operated by three partners: The University of Manchester (which designed the methodology and undertook data analysis), GMCA (which co-ordinated the delivery of energy advice), and representatives from the charity Groundwork (which directly undertook the provision of energy advice and collection of primary data). Prior to starting community engagement activities, a baseline assessment in early 2019 established a benchmark for energy poverty and energy-related behaviour. The assessment was mostly based on existing secondary data, namely the UK Census and English Indices of Deprivation. It was supplemented by insights from a focus group, and a review of relevant academic and grey literatures. To assess the extent of energy poverty in GM, we used the "Low-Income High Cost" (or LIHC) measure. This indicated that energy poverty is highly skewed towards inner-city areas in GM, with the southern and northern districts surrounding the city centre of Manchester and Salford being particularly vulnerable. The central areas of other boroughs, particularly those in the north and east of GM (Bolton, Bury, Rochdale, Oldham) were also found to be at elevated risk.

The baseline assessment also included an analysis of the spatial distribution of energy vulnerability drivers. The areas surrounding the urban cores of Manchester and Salford were found to have a high proportion of households reliant on electric central heating, which is typically more expensive than gas central heating, or without central heating altogether (and so likely reliant on plug-in electric heaters, single-room gas fires, or burning solid fuels for heating). In contrast, housing in the other metropolitan boroughs of GM was more likely to be heated by gas; however, such areas also had a higher proportion of homes with low levels of energy efficiency compared to central areas. Aside from material factors, high levels of income deprivation were found to be present in all of metropolitan districts, with especially high concentrations in central Manchester and greater levels of affluence in the outer ring of GM. Other forms of social marginalisation that may increase the vulnerability to energy poverty – such as older age, disability, or poor health – were

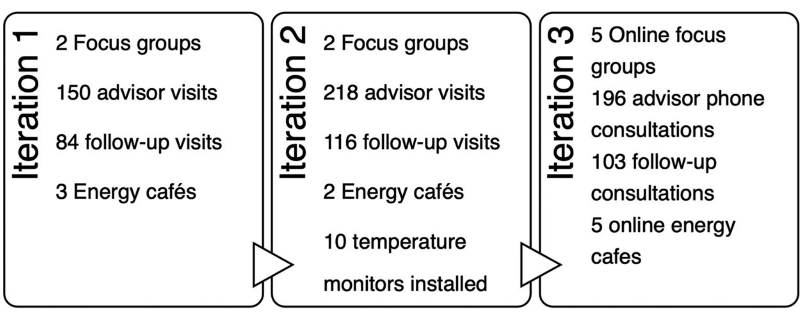

Figure 1. Outline of the LL process in GM.

relatively dispersed throughout GM. Overall, the findings indicated that both central and outer areas of GM were characterised by conditions that are likely to increase vulnerability to energy poverty.

The LL operated in three distinct "iterations", which took place in six-month intervals from March 2019 (Figure 1). The main element of the Lab were energy advisor consultations, involving a Groundwork "Green Doctor" (GD) and householders vulnerable to energy poverty. GDs are expert energy advisors who specialise in working with people vulnerable to energy poverty. During these consultations, they provided personalised advice on how the householder could lower their energy costs and keep their homes warm. During iteration 3 of the LL, the consultations were conducted via telephone. Across the three iterations, 565 households received direct advice through the consultations. Ten of the consultations during Iteration 2 of the LL involved the installation of temperature and humidity monitors which automatically recorded room temperature every fifteen minutes. The GDs offered the monitors to households that they judged, based on their observations, to represent relatively "typical" conditions of those they visited. Follow-up energy advisor consultations, taking place up to 2 months following the initial advisor consultation, were also implemented in all Iterations of the LLs. They assessed the outcomes from the first consultation using a customised *ex-post* survey, and provided further advice where necessary. The consultations were conducted in-person during Iteration 1 and 2, and via telephone in Iteration 3 of the LL. Across the three iterations, 303 households were engaged via the follow-up visits.

Focus groups with expert stakeholders were held at the beginning of each LL. These were used to discuss the key energy poverty-related challenges in GM, to plan in detail the STEP-IN actions, and to evaluate findings from the previous iterations of the Lab. A further key element of the Lab were Energy cafés, which were held in several neighbourhoods. Energy cafés are a form of collective and informal energy advice provision, in which energy advisors host an open stall in a public space (Martiskainen, Heiskanen, and Speciale 2018). These acted primarily as a recruitment tool for the one-to-one advisor consultations, but also involved the direct provision of advice. Across the three iterations 10 energy cafés were held, visited by 271 people. During the COVID-19 restrictions, the cafés were held online using an instant messaging format.

In all iterations of the LL, high proportions of households self-reported symptoms of energy poverty during the initial advisor consultations – approximately half of respondents were unable to keep their home adequately warm, up to two thirds had draughty windows and doors, and in Iteration 2 almost 90 per cent reported cutting back on heating usage. The percentages recorded by the GDs were well above the rates of energy poverty modelled using the LIHC indicator during the baseline assessment. This indicated that the advice programme was effective at identifying and reaching households who are vulnerable to energy poverty. During Iterations 1 and 2, there was a substantial decrease in the proportion of households unable to pay their energy bills on time at the follow-up consultations compared to the initial visits (Figure 2). While these self-reported figures need to be interpreted with some caution, the extent of the decreases does suggest that the advisor consultations were often able to alleviate some energy poverty symptoms among visited households. In contrast, Iteration 3 demonstrated the opposite trend for some indicators, with a substantial *increase* in the proportion of households unable to pay their energy bills on time between the first and second advisor consultations.

During Iterations 1 and 2 of the LL, the GDs were able to assist households through four main methods. First, and perhaps most importantly, households were helped in switching their energy

Table 1. Percentage of consulted households that undertook energy saving measures, in each Iteration of the Manchester LL.

	Iteration 1	Iteration 2	Iteration 3
Switching energy tariff or supplier	25%	20%	3%
Referral to further support service	29%	29%	38%
Adopting more optimal usage of heating controls	6%	25%	3%
Installing of small energy efficiency measures	63%	82%	2%
Upgrading boilers	25%	22%	1%

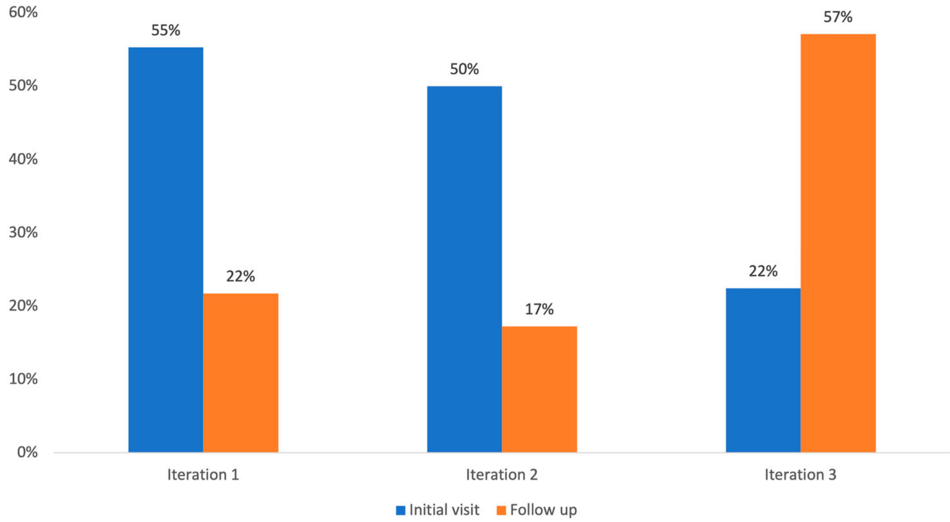

Figure 2. Percentage of respondents reporting an inability to pay their bills on time during initial and follow-up advisor consultations, for each iteration of the Manchester LL.

tariff, with 25 per cent of LL participants in Iteration 1 and 20 per cent in Iteration 2 having undertaken this measure by the time of the follow-up consultation (see Table 1). As acknowledged in the GDs' fieldnotes: "I have switched the resident to a new supplier making a saving of £318" (Iteration 1). However, in Iteration 3 only 3 per cent of respondents undertook this measure. Second, the GDs could refer households to sources of further advice and financial support, such as "income maximization" services that ensured people were claiming all of the social security to which they were eligible. This was especially common in Iteration 3, with 38 per cent of households being referred to a further support service, compared to 29 per cent in Iterations 1 and 2.

Third, householders were advised on everyday behavioural changes that could result in a decrease in their energy consumption and costs. Most commonly, this related to GDs helping LL participants to understand how to use their heating controls most efficiently. In Iteration 2, just under a quarter of households lowered their thermostat temperature following the first Green Doctor consultation, whereas just under 3 per cent did so in Iteration 3. The GD fieldnotes again supported this quantitative data and emphasised the savings that made in some cases, e.g. "[The household is] Spending less money on gas, went from around £40/50 a week, to about £15, [because they are] regulating heating better" (Iteration 2) or "Explained how to work heating system as was using it wrong, which has saved loads of money on the gas spend" (Iteration 2).

Fourth, GDs could install "small" energy efficiency measures (such as LED bulbs, draught excluders, reflective foil behind radiators, and chimney balloons). These were the most common energy saving measures of all, with the majority of visited households in Iteration 1 and 2 undertaking these, but just under 2 per cent doing so in Iteration 3 (Table 2). And fifth and finally, a significant proportion of respondents in Iterations 1 and 2 were also eligible for more substantial energy

Table 2. Percentage of consulted households that undertook energy saving measures, in each Iteration of the Metsovo LL.

	Iteration 1	Iteration 2	Iteration 3
Heating system maintenance	25%	16.5%	9%
Adopting more optimal usage of heating controls	20%	13.5%	19%
Decided to implement insulation measures in the near future	16%	7.5%	2%
Improved energy saving habits	12%	28.5%	47%
Improved quality of life	35%	54%	32%

efficiency measures – specifically, a new heating boiler. In Iteration 3, only 1 per cent of respondents had such a measure installed. Overall, the LL was relatively effective at alleviating (if not completely eliminating) energy poverty among visited households during Iterations 1 and 2, and this can be partly attributed to the effectiveness of the various energy and financial saving measures encouraged by the GDs. In contrast, Iteration 3 was much less effective at alleviating energy poverty and in implementing energy and cost saving measures through. This can be attributed to factors relating to the COVID-19 pandemic and associated lockdown policies, which we reflect upon later in this paper.

The Metsovo LL

The Greek LL operated in Metsovo, a mountainous settlement situated at an altitude of 1100 m. Metsovo has a total of 2503 residents living in about 890 households. The share of the elderly people in the population (i.e. over 65 years old) is 24 per cent (Greece's average: 18 per cent). The majority of the population works in livestock, cheese-making, winemaking, forestry, folk art, textiles and manufacture of hives and barrels. The unemployment rate is significantly lower than the national average. The Lab itself was operated by the National Technical University of Athens (NTUA) in collaboration with the Regulatory Authority for Energy and the Municipality of Metsovo.

At the start of the LL, a baseline survey was conducted to ascertain a benchmark for energy poverty and energy-related behaviour in the area of Metsovo. The baseline survey used both secondary and primary data gathered by means of a social survey to a representative sample of 300 households in the LL area. The LL team explored a wide range of issues, including living and housing conditions, housing infrastructure, heating systems, energy expenses, income, and other socio-demographics. The analysis showed that energy poverty is a serious problem due to harsh climate conditions, the old building stock (almost 70 per cent of the dwellings were built prior to 1980, and nearly 6 out of 10 dwellings had no insulation), as well as low income and high energy cost problems (between 2009 and 2014, fuel prices rose considerably while average annual incomes shrank by about 29 per cent). It was also established that heating expenses represented about 75 per cent of annual household energy costs, otherwise estimated at 3100 euros per household.

The survey found that energy poverty is mainly related to high energy burdens, with the mean energy affordability ratio standing at 23 per cent, against a standard deviation of 12.5 per cent (the median was 22 per cent). Approximately 90 per cent of surveyed households had energy burdens above 10 per cent, although this figure should be placed in the context of possible overheating practices: almost 64 per cent of the respondents stated that the ideal home temperature during winter is more than 21 degrees C. At the same time, fewer than 40 per cent of households thought they could not keep the home adequately warm. Condensation, damp and mould problems were reported by between 23 per cent and 32 per cent of households; even though electricity disconnections were not considered a serious problem (at less than 1 per cent of the survey sample). About 15 per cent of the households had cut back on food, and 47 per cent had reduced the heating of their homes (in terms of hours of operation or numbers of rooms that were kept warm). In light of these trends, the LL team constructed a composite energy poverty risk index combining the presence of *(i)* an inability to keep the home adequately warm; *(ii)* housing faults (such as mould and damp); *(iii)* arrears in energy bill payments; and *(iv)* cut-backs on essentials such as food and lighting. Index values could range from 0 to 4, depending on the number of challenges that were encountered by a given household. It was found that approximately one fifth of households faced a very high energy poverty risk (where the index value was over 4), with a majority of households – approximately 60 per cent – registering a low or negligible level of risk (with index values below 1).

Just as in Manchester, the first two LL rounds commenced from March 2019, unfolding across two subsequent six-month intervals (Figure 3). Other than the training of energy advisors – which took place only during the first iteration – each of these two LL rounds included an energy café with

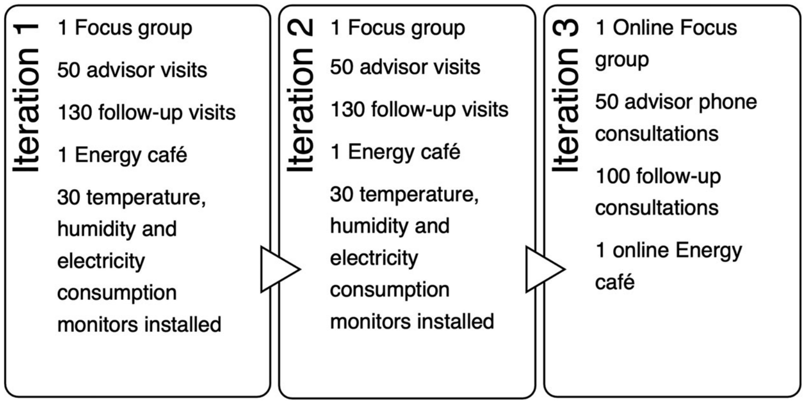

Figure 3. Outline of the LL process in Metsovo.

different stakeholders (citizens, policy-makers, local trade associations, NGOs). A total of 50 households were recruited in every iteration for the provision of energy advice, and the observation of domestic energy circumstances via devices such as smart meters, humidity and temperature monitors. The participating households were visited for up to four times by the energy advisors, who collected information about residential and household characteristics (in part, via thermal cameras and exhaust-gas analysers to examine the energy efficiency of the built fabric and heating system), provided support regarding the operation of energy systems and energy bills, provided personalised advice based on the measurements collected from the visits (and the monitoring equipment where available), and assessed the effects of interventions previously implemented. The Lab was also underpinned by the operation of an Information Centre aimed at offering a physical one-stop-shop for the provision of energy assistance and information. It should be noted that a number of methodological adaptations were made during the second LL round based on lessons learned from the first iteration, particularly with regard to the energy café format, and the energy advisors' actions during the home visits. Moreover, energy diaries were distributed to all target households and changes to the IT tools were made.

The third LL round took place between June and December 2020. The COVID-19 outbreak created new scientific, methodological and ethical challenges that prompted methodological adjustments. Due to the pandemic-related restrictions, all LL activities functioned remotely in the form of energy café webinars, online information campaigns, personal communication via phone, email or online chats, development of online apps, and telephone interviews. From a methodological perspective, this helped test the effectiveness of the remote provision of advice and assistance. Moreover, the monitoring equipment stayed at the same households from the previous iterations, not only as a matter of ethics and compliance with safety measures suggested by the Greek authorities, but also as a means to collect empirical data and study the impacts of COVID-19 on energy vulnerability.

Overall, 150 households were directly involved in the LL activities across all three rounds. The data collected from the Lab was analysed using statistical and building energy efficiency software packages. Data inputs included the monitoring equipment, the energy advisor questionnaires, as well as fine-grained weather information from the meteorological station operated by NTUA in Metsovo. On average, subjective energy poverty indicators showed improved values compared to the initial assessment: 14 per cent of households stated that they were unable to keep the home adequately warm, with a similar percentage stating that they experienced arears in energy bills; moisture and mould problems were present in 30 per cent of homes. The most vulnerable households were those who lived in low-energy efficient and old dwellings. The required heating costs for uninsulated houses were almost 45 per cent above the LL average, and the mean indoor temperature was 1 degree C lower than for insulated homes of a similar type. Another vulnerability factor was the lack of central heating – where people used electric devices, fireplaces and stoves for this purpose, differences of up to 10 degrees C were recorded among unheated and heated rooms. Larger households that relied on special electricity tariffs (e.g. social or night tariffs) were also shown to be more vulnerable. They tended to underestimate the cost of electricity by using electric heating devices during peak tariff period. However, other socio-economic characteristics (such as the presence of young children, older people, long-term unemployed, disability, as well as being a single parent or not owning one's home) did not play a significant role in determining energy vulnerability. This may be due to the fact that rates of unemployment and private rented housing were low in the area, as was the presence of single-parent families.

While the LL demonstrably led to savings in energy consumption (9, 5 and 4 per cent in the first, second and third rounds, respectively) (Figure 4), its benefits to the participating households extended to a range of adjacent domains. Approximately 40 per cent of households stated that they noticed an improvement in the quality of their life (see Table 2), mainly by thanks to increased levels of thermal comfort in their homes, as well as the reduction of energy costs and housing faults. There were marked increases in the use of energy saving habits, the adoption of improved heating controls, heating system maintenance, and, to a lesser extent, intentions to implement energy efficiency measues. Almost three quarters of the households felt that LL activities were useful to them in terms of everyday habits concerning home ventilation, thermostat setting, energy literacy, as well as heating system maintenance and efficiency.

The Nyírbátor LL

In Hungary, the LL centred on the district of Nyírbátor in the eastern part of Hungary. Approximately 50,000 people live in this area, in more than 20 predominantly rural settlements. With a population of 12,000, Nyírbátor is the largest of the five small towns that can be found in the district. Overall, the region is demographically younger and socio-economically poorer than the Hungarian mean, with a higher-than-average unemployment rate. The Lab itself was operated by three partners: Maltai (a humanitarian charity) organised the home visits and provided the social and institutional infrastructure of the LL; Ariosz (a research agency) was responsible for

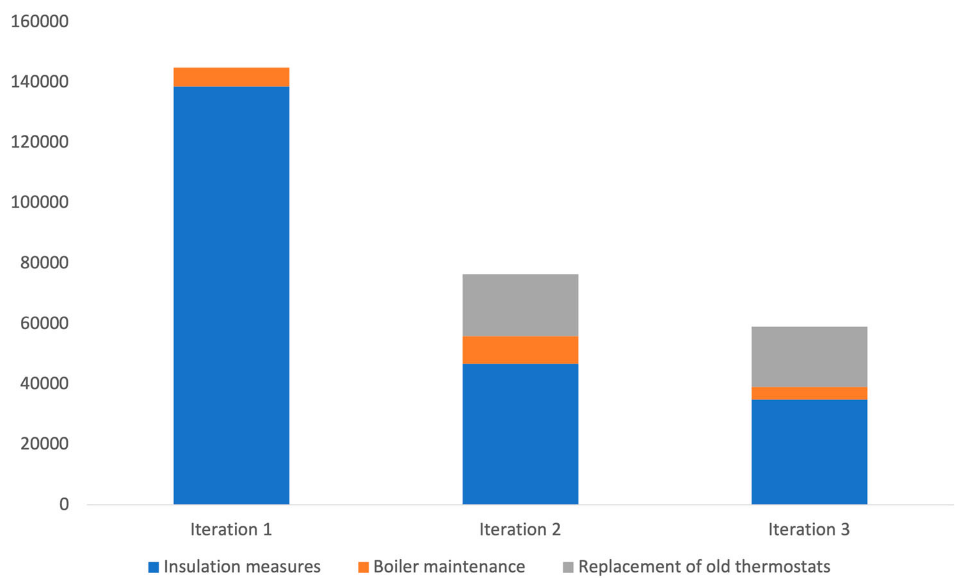

Figure 4. Total heating energy savings (in KWh) resulting from the Metsovo LL.

the methodological framework of the project; and E.ON (the main energy utility in the area) supported the technological implementation.

To assess the initial situation in the region, the LL team conducted a questionnaire survey of 305 households, to collect data on energy use, needs, access, and other aspects of energy vulnerability. The survey was used to segment the target group and to explore the needs of local citizens. It included questions about housing conditions, coping strategies to reduce energy bills, and thermal comfort. The most common problem was that dwellings were not comfortably cool during the summer (32 percent of respondents) and not comfortably warm in the winter (28 percent). It was established that 37 per cent of households were restricting their use of essential items and services in order to meet their energy needs. The two most typical strategies were cutting back on clothes purchases (29 percent of respondents) and heating (27 percent of respondents). In terms of the measurement of energy poverty, the LL constructed a vulnerability score combining the energy burden ratio and a consensual energy vulnerability index based on Bouzarovski and Tirado Herrero (2017), which combines the inability to pay for energy (0.5 weight), the presence of energy arrears (0.25 weight) and inadequate housing conditions (0.25 weight). Based on this typology, 51 percent of households were found to experience a moderate energy poverty risk due to either a high energy burden or a high energy vulnerability index, while 5 percent were at a high risk due to being affected on both counts.

The assessment was followed by three LL iterations, principally relying on energy cafés and home visits (Figure 5). Each iteration lasted approximately six months, starting from March 2019. LL activities were mainly carried out by home energy advisors. While the advisors were trained social workers, they needed further specialist instruction in order to acquire customised knowledge of energy-related advice work, energy access, and energy literacy. The home visits typically involved a brief presentation of the LL aims and services, the data collection process, and ethics issues. Participants were asked to complete an energy survey that allowed the advisors to generate a "personal advice sheet", providing an overview of the household's energy use patterns, and leading to personalised energy recommendations.

Energy cafés were held throughout the LL. They enabled the LL teams to showcase the benefits of the programme, while introducing the basic methodology of home visits, increasing the local visibility of the project, and understand citizens needs. The outcomes of the cafés and advisor visits in the first LL iteration led to a transformation of the engagement strategies and approaches used during the second iteration. Given the lack of trust towards outside actors in many of the smaller settlements in the area, it was decided to focus efforts on settlements where the LL team had close ties to the local community. The new engagement model led to increasing rates of participation. Moreover, one of the most striking results of the first LL iteration was that more than 30 per cent of the involved

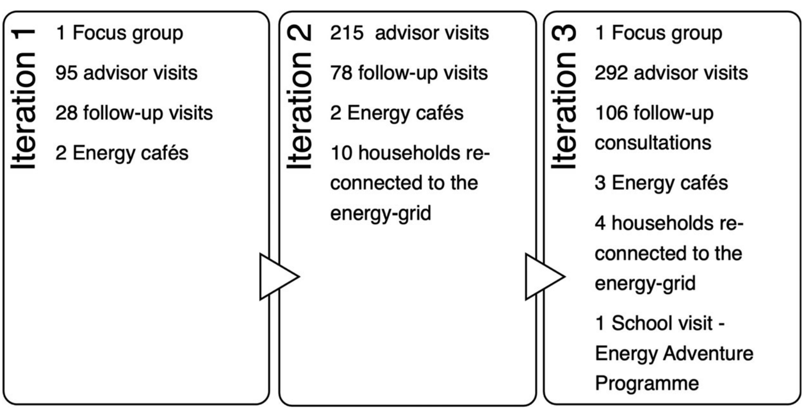

Figure 5. Outline of the LL process in Nyírbátor

household did not have formal power grid access. The LL teamed up with the Emerging Settlements Programme – a government initiative to provide development measures for deprived areas – to address the issue. The third LL iteration commenced with a focus group to discuss adaptation strategies in relation to the Covid-19 pandemic. It was decided to maintain the home visits and energy cafés, while implementing social distancing measures and mask-wearing. A subsequent increase in Covid-19 case numbers led to the cessation of all in-person work, and the undertaking of some activities via phone or indirect contact (remote completion of questionnaires). This iteration also involved the installation of additional technical measures, services to support the reconnection of households to the grid, and educational activities for children.

A total of 605 households took part in the LL. Overall, 60 percent of the participant households could be considered energy poor, and more than 10 per cent of respondents did not have formal access to the electricity grid. The LL team developed a customised approach to address this situation, leading to the granting of grid access to 14 households. Although the LL resulted in improvements in housing conditions as a whole, it was also found that the COVID-19 pandemic led to higher levels of household debt, as well as job losses and wage decreases. This, in turn, worsened the overall energy poverty picture. Nevertheless, the LL helped prevent a significant deterioration in the quality of life, given the pervasive extent of domestic energy deprivation across the case study area as established at the start of the process.

Thus, 13 per cent of households experienced an improvement in housing conditions (reduced prevalence of mould, damp, condensation or a leaking roof, more comfortable temperature levels), 15 per cent saw a reduction in bill arrears, and the the quality of life improved for nearly a fifth of all participants (Figure 6). Nearly 37 per cent of the respondents experienced at least one of these improvements (Figure 6). While more than a fifth of Roma and multi-children families reported reductions in bill arrears, this figure was close to zero for single pensioners, who had did not have arrears to begin with. At the same time, 30 per cent of single pensioner and 20 per cent of Roma households, respectively, reported improvements in the quality of life. LL activities (mainly home visits) had a measurably positive impact on the participants' domestic energy circumstances, with 67 percent undertaking energy efficiency improvements. The LL team estimated that

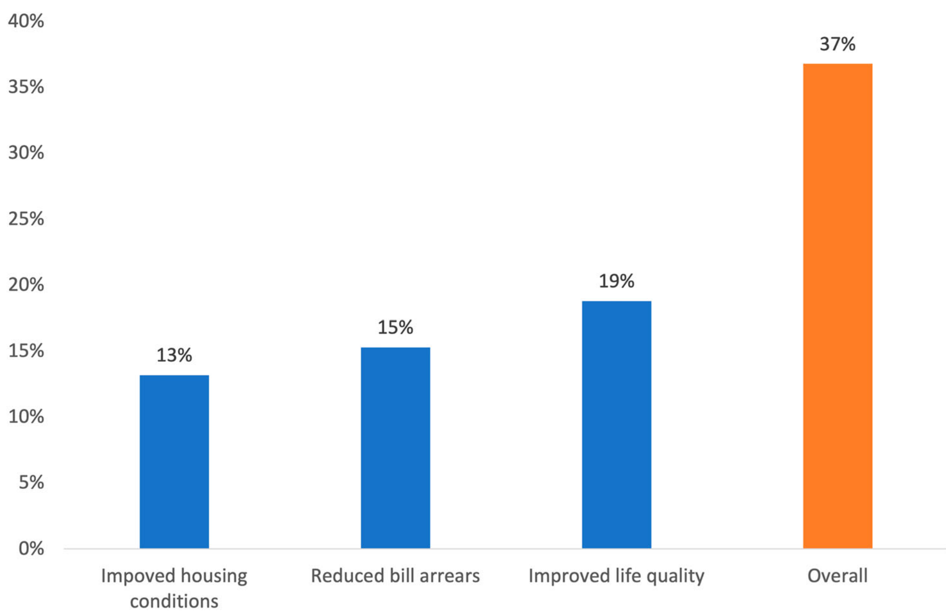

Figure 6. Quality of the life impacts linked to the Nyírbátor LL.

participants' energy bills decreased by 5.3 percent across the lifetime of the Lab. However, this was not accompanied by a significant change in levels of energy consumption.

Energy poverty trends during the pandemic: LL findings

As was noted above, the COVID-19 pandemic prevented the LLs from conducting most in-person activities. Instead, the majority of advice was, unavoidably, provided via "remote" methods, namely telephone calls or internet communication. At the same time, new pandemic-related questions were added to the evaluation questionnaires to examine changes in the socio-economic status (e.g. employment status and income) and in energy-related behaviour (e.g. usage of heating system and electrical appliances) of the households. These questions were largely added in response to evidence about the direct financial implications of COVID-19 and associated lockdown policies. Many LL participants experienced job losses or wage reductions, resulting in a reduced income. At the same time, lockdown policies meant that people were spending increased amounts of time at home and so consuming greater amounts of energy, resulting in higher bills. This combination of reduced income with increased energy costs was noted by the energy advisors as severely impacting the lives of many the respondents they spoke to during Iteration 3 of the LLs.

As a whole, there was evidence of widespread energy-related hardship as a result of the pandemic (Table 3). In Manchester, nearly two thirds of the interviewed households reported spending more time at home, and nearly half used their appliances more. Changes in occupational status affected about a fifth of the participants, with a just over a quarter experiencing reductions in income. Nearly three fifths saw their energy bills increase, with the overall combination of circumstances resulting in around a fifth being in arrears on their energy bills. In the Greek LL, significant differences existed between the households depending on the housing characteristics, socio-demographic, and heating system characteristics. Low-income households were forced to spend an even higher proportion of their income on heating and electricity costs to achieve the desired indoor temperature. In Hungary, there was less change in the time spent at home or the increase in bills than in the other two LLs, but some consequences of the pandemic were striking – notably arrears in bill payments, with more than half of households being unable to afford adequate food. This may be attributed to the unavailability of free school meals during lockdown.

The switch to remote activities appeared to have a negative effect on the efficacy of the advice provision. In-person communication has previously been widely noted as important for building the relations of trust that are essential for advice to be believed and acted upon (e.g. Irwin 1995; Simcock et al. 2014; Warren and Foulds 2020; Wilson, Crane, and Chryssochoidis 2015). As such, householders may have been less inclined to trust and act upon advice communicated remotely. This helps explain the greatly reduced percentage of householders implementing recommended behaviour changes during the third iterations of the Manchester, and to some extent Greek, LLs. Furthermore, during in-person consultations in Iterations 1 and 2, the energy advisors would often directly install small energy efficiency measures themselves, but this was not possible during Iteration 3 – hence the dramatic decrease in measures deployed. In Greece, it was found that remote assistance could not reach some of the most vulnerable households, e.g. those who do not have internet access (or even telephone access in many cases). This was

Table 3. Pandemic-related effects on household well-being and energy circumstances during the third LL iteration.

	Manchester	Metsovo	Nyírbátor
Spending more time at home	63%	76%	46%
Increased use of appliances	48%	64%	50%
Change in occupational status	21%	40%	33%
Reduction in household income	26%	45%	–
Increased energy bills	59%	58%	24%
Arrears in bill payments	22%	10%	32%
Inability to afford adequate food	16%	–	54%

also reflected in the achieved energy savings in the three rounds. In Hungary, government introduced a moratorium on bill arrears during the pandemic. The energy advisor reports indicate that most households took advantage of this opportunity.

Discussion

Experiences from, and the results of, LL interventions demonstrated the highly spatially-contingent nature of energy advice and intermediation (Warren and Foulds 2020). The urban and regional geographies targeted by the project shaped both the character and outcomes of the energy measures deployed. This includes both the material "hardware" of low-carbon transformations, as well as the social "software" through which LL participants engaged with each other and the desired changes in energy-use practices, routines and habits. In terms of the former, we found that climatic factors, the structural nature of the housing stock, and systems of energy provision all influenced the delivery of energy efficiency amenities and the retrofitting of housing more generally. In Metsovo, the mountainous nature of the area, and the lack of networked systems of energy provision (other than electricity), meant that local residents only had a limited range of choices to heat their homes (resulting in, inter alia, air pollution problems at the "air-energy nexus" see Bouzarovski and Robinson 2022). Climatic factors, however, meant that summertime energy poverty was not (yet) a challenge, in contrast to the rest of Greece – pointing to the multi-scalarity of energy injustices, and the need for adopting customised energy poverty alleviation approaches in line with the needs of individual regions or settlements (in a situation where most policies to address energy injustices are formulated either at the transnational or national level).

In Nyírbátor, we similarly encountered a limited range of heating options, with households facing both summertime and wintertime energy poverty. This area was characterised by a high degree of economic and social informality, which also affected how energy was used – and similarly required the adoption of customised approaches. Manchester was possibly one of the most challenging intervention sites, partly due to the sheer size and complexity of the case study area. The LL had to encompass a very wide range of socio-spatial diversities: from various forms of intersectional inequality (where it is known, for example, that ethnic minorities face proportionally greater difficulties in accessing adequate energy services in the home), see (where it is known, for example, that ethnic minorities face proportionally greater difficulties in accessing adequate energy services in the home – see Bouzarovski et al. 2022), to the wide range of energy supply situations (various forms of gas, electricity, heat), and the variety of housing typologies: high-density apartment buildings, lower-density semi-detached houses in the suburbs, and a smaller proportion of fully detached homes. The polycentric urban structure introduced additional complexities, with each individual borough within the agglomeration having its own distinctive town centre, inner-city and suburban areas. Yet LL actors managed to develop successful strategies to address the vastly different residential circumstances of participating households, mainly thanks to the iterative character of the LL, supported by auxiliary events (workshops, focus groups) where future and past activities could be evaluated, discussed and deliberated; possibly the largest challenges occurred in situations that were beyond the control of the LL itself, such as in the private rented sector.

The LLs were strongly supported by the operation of intermediary organisations from the third sector – community activists, advocacy groups, aid charities, religious groups. These variegated networks and institutions offered a range of services and functions beyond the provision of energy advice: identifying and approaching target households, providing social assistance and mental health support, allowing access to state-funded programmes, and facilitating the interaction between LL participants and other actors. In this sense, the intermediaries essentially covered roles that would traditionally be the remit of the state, but have been outsourced due to roll-back neoliberalism in the case of Greece and the UK (Hughes and Ketola 2021), and the post-socialist transformation in Hungary (Bohle and Greskovits 2019). Also of importance here has been the inability of the state to develop its competences in step with the new demands created by the low-carbon transformation – even in a high-income economy like the UK, where climate concerns are high on the political agenda. In undertaking their roles, the intermediaries mobilised significant amounts of capital, skills and emotional labour across multiple material sites. Even if they can be described as "system intermediaries" (Kutter, Wolf, and Rothbarth 2023), they also perform some of the roles that are played by "process" and "user" intermediaries in e.g. Kivimaa et al.'s (2019) framing; this suggests a need for introducing a more explicitly spatial, practice-based understanding of intermediation in sustainability transformations, beyond the systems innovation and Multi-Level Perspective-influenced approaches that have dominated the literature (Dutt 2023).

The LLs also demonstrated how energy assistance can help facilitate the diffusion of low-carbon technologies, while moving existing energy-use habits and knowledge towards more energy efficient patterns. Even seemingly minor changes in everyday energy use routines and infrastructures – such as optimising heating controls in line with room occupancy, as well as installing the "small measures" described above – were associated with tangible reductions in energy bills. Savings were even greater in instances where householders were found to be overpaying for energy, or were able – thanks to the signposting of support, or the provision of direct material assistance – to access funds for more ambitious energy efficiency investment. It is notable, however, that material reductions in energy consumption were limited, despite significant decreases in financial household energy expenditure. This can be attributed to the previously pervasive practices of energy underconsumption among LL participants, owing to the presence of energy poverty. The effects of LL interventions were thus primarily reflected in the improvement of thermal comfort and energy use related well-being more broadly, rather than specific decreases in energy use *per se*.

Despite their multiple benefits, the LL interventions had clear limitations, determined by wider social, spatial, political and economic contingencies. One of the challenges that arose methodological – there is currently a lack of scientifically robust energy poverty indicators that allow for establishing the presence of the condition through direct measurement. One of the most common quantifications – LIHC – has previously been shown to disproportionately identify inner-city households as vulnerable, and to be insensitive to short-term changes in incomes and prices (Robinson, Bouzarovski, and Lindley 2018). It is also a "modelled" indicator that cannot be used to identify energy poor households "at the doorstep" (Bouzarovski and Thomson 2018). A second issue related to the nature of public participation and inclusion: even if LLs are predicated upon novel forms of knowledge co-creation and co-production, one might query the extent to which target households genuinely have the opportunity to influence the socio-technical fundamentals of the interventions themselves. Energy cafés play an important role in addressing this deficiency, by creating a more direct route of dialogue and engagement. Third, the LL could only partly address the wider social disparities related to income, disability and other socio-demographic household characteristics. All three case study areas experienced major structural issues that will continue to contribute to the persistence of energy poverty in years to come, particularly in terms of addressing the poor energy efficiency of the housing stock. This is against a background of significant and rising levels of income inequality in most areas, a recent history of cuts to public services (particularly in Greece and the UK), as well as energy price pressures.

Conclusion

The three LLs investigated in this paper developed a rich assemblage of organisational actors, activities and interventions aimed at addressing energy injustices via different forms of citizen engagement. The LLs provided an instrument for improving the energy performance of the residential stock, heating systems and domestic appliances, while placing disadvantaged groups at the centre of the low-carbon transformation. While continuing to function during the challenging times of the COVID-19 pandemic, the LLs generated innovative ways to continue supporting energy sustainability, thermal comfort, and citizen well-being, while collaborating with relevant intermediaries, state programmes and associated modalities of energy advice to deliver interventions. The LLs also promoted and developed the social capacities, relations and emotional well-being of participants. As a whole, they helped forge a distinct form of climate repair, via multiple dynamics of infrastructural labour and collective care (Bouzarovski 2022; Knuth 2019; Lopes et al. 2018).

The core aim of this paper was to examine the conditions under which LLs can help address energy poverty, and so contribute to an equitable low-carbon transformation via a specific form of socio-technical intermediation. The results of all three LLs pointed to significant quality of life improvements and climate mitigation benefits, indicating that LLs can provide effective tools to promote comprehensive residential energy improvements for socially marginalised groups. At the same time, they also revealed the significant systemic challenges associated with ambitious efforts to address infrastructurally-embedded inequalities on the path to a low-carbon future, further exacerbated by the legacies of austerity and the progression of the global Covid-19 pandemic.

When considered alongside broader insights on the relationship between energy efficiency investment and energy poverty (Aranda et al. 2017; Sahakian et al. 2021), these findings have important initial implications for wider practices of decarbonisation in socially and spatially challenging contexts. First, they mean that energy behaviour changes and small-scale energy efficiency measures are unlikely to lead to significant energy poverty decreases unless they are accompanied by carefully considered efforts to improve the delivery of low-carbon interventions. However, even minor actions may drive more immediate and direct improvements in the lives of highly vulnerable residents, especially if they are followed up by referrals to energy efficiency programmes. Second, LLs can be used to provide fine-grained information – in both temporal and spatial terms – on citizen responses to, and relationships with, energy efficiency and housing retrofit measures, particularly. And third, LL approaches can be employed as tools for evaluating the effectiveness of existing energy efficiency schemes, while developing new methods for reducing energy poverty. One of their most lasting benefits is the development of deep and evidence-based knowledge on direct quality of life improvements, especially in terms of new ways of identifying and targeting vulnerabilities "at the doorstep" and within the community.

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