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DOI

[10.5334/bc.591](https://doi.org/10.5334/bc.591)

Publication date

2025

Document Version

Final published version

Published in

Building and Cities

Citation (APA)

Ricci, D., Leiwakabessy, C., van Wieringen, S., de Koning, P., & Konstantinou, T. (2025). Co-creating justice in housing energy transitions through energy living labs. *Building and Cities*, 6(1), 747-766. <https://doi.org/10.5334/bc.591>

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Co-creating justice in housing energy transitions through energy living labs

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ABSTRACT

Justice-oriented, context-sensitive approaches that go beyond technocratic top-down decision-making processes can facilitate and improve the retrofit and energy transition of housing. Urban living labs (ULLs) are emerging as valuable collaborative spaces for learning and co-creating strategies. Although increasingly adopted in urban planning and placemaking, their potential to operationalise procedural justice by facilitating inclusive and accessible processes in energy renovation remains unexplored. Drawing on fieldwork notes and expert interviews, this study examines the initial phases of four Dutch energy living labs (ELLs) implemented in vulnerable neighbourhoods to support housing retrofit and energy transition projects. It analyses how they foster residents' inclusion and connect institutional agendas with residents' everyday practices and living environments. The findings reveal how ELLs play a strategic role in enhancing residents' visibility, creating multistakeholder relational arenas that stimulate interorganisational learning. Researchers in ELLs mediate between theory and situated practices, facilitating energy justice implementation by challenging established professional assumptions. Flexible, locally guided forms of ELLs help address process shortcomings, supporting more socially embedded retrofit and energy transitions, and notably contribute to a) resident engagement and representation, b) technical design and performance and c) collaborative and responsive governance approaches.

PRACTICE RELEVANCE

This study provides actionable insights into how ELLs can make housing energy transitions more inclusive by linking institutional strategies with residents' everyday practices and living environments. In vulnerable neighbourhoods, the early phases of ELLs already facilitate residents' engagement and representation, strengthen trust and improve access

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KEYWORDS:

urban living labs; retrofit; energy-efficient renovation; just transition; procedural justice; co-creation; net zero

TO CITE THIS ARTICLE:

Ricci, D., Leiwakabessy, C., van Wieringen, S., de Koning, P., & Konstantinou, T. (2025). Co-creating justice in housing energy transitions through energy living labs. *Buildings and Cities*, 6(1), pp. 747–766. DOI: <https://doi.org/10.5334/bc.591>

to information. The findings highlight the value of flexible forms of ELL that can adapt to local challenges. For practitioners and policymakers, the study underscores the importance of investing in the formative stages of ELLs, ensuring adequate time and resources for relationship-building. Collaboration with researchers supports reflexivity and mutual learning. Key actions include embedding co-creation in renovation programmes, aligning technical design with lived experiences, and strengthening collaborative governance.

1. INTRODUCTION

Living labs (LLs) are increasingly recognised as effective approaches for user-centred design, collaboration, and real-world experimentation in urban transition projects and housing energy renovations ([Bridi *et al.* 2022](#); [Bulkeley *et al.* 2016](#); [Kowaltowski *et al.* 2024](#)). They bring together researchers, public and private partners and end users to co-create innovative solutions in real-life environments ([Puerari *et al.* 2018](#); [Voytenko *et al.* 2016](#)). This collaborative orientation moves away from purely technocratic methods in energy transition projects that often overlook social practices and local contexts ([Breukers *et al.* 2017](#); [Broers *et al.* 2022](#); [Karvonen 2013](#); [Manktelow *et al.* 2023](#); [Ricci *et al.* 2025](#)). When applied to sustainability challenges in urban settings, LLs are defined as urban living labs (ULLs): a collective infrastructure open to innovation, experimentation and social learning ([Blezer *et al.* 2024](#); [Bulkeley *et al.* 2016](#)). ULLs act as place-based interventions – at the neighbourhood, district or city scale – where stakeholders co-develop and test technologies, services or social arrangements aligning with local needs and values ([Bulkeley *et al.* 2016](#); [Rizzo *et al.* 2021](#); [Scholl & Kemp 2016](#)). These features are particularly critical in residential building interventions, such as low-carbon heating systems and building renovations, which directly affect personal aspects of residents' lives, including their domestic environments, energy and comfort practices, and associated costs ([de Feijter & van Vliet 2021](#); [van Wieringen *et al.* 2025](#)). As sociotechnical processes, energy transitions and renovations require centring residents' lived experiences to address inclusion and equity ([Ricci *et al.* 2025](#)).

While calling for a rapid scale-up of renovations to meet the 2050 climate neutrality targets ([European Commission 2020a](#)), EU policies and initiatives also stress the need for socially just renovation strategies ([BPIE 2022](#)), promoting community engagement in designing sustainable and inclusive spaces ([The New European Bauhaus: European Commission 2020b](#)). Achieving this requires not only technical capacity and policy frameworks but also context-sensitive delivery models, collaboration and third-sector involvement ([Wade & Visscher 2021](#)). However, despite their promise, local participatory approaches, such as ULLs, are more established in public-space and placemaking projects than in domestic energy interventions. When energy renovations disregard residents' capabilities in engagement processes ([Axon & Morrissey 2020](#)) and overlook neighbourhood-level social, cultural and material conditions, they risk generating injustices ([Charles *et al.* 2025](#); [Hanke *et al.* 2023](#)).

Energy poverty further restricts residents' ability to meet basic needs and engage in complex renovation processes ([Tozer *et al.* 2023](#)), exemplifying the structural exclusion of disadvantaged groups from renovation benefits, termed retrofit poverty by Willand *et al.* (2020). In the Netherlands, energy renovation efforts have often resulted in residents facing higher rents, lack of trust, inadequate information, resident–technology mismatches and disruptive interventions ([Boess 2022](#); [Breukers *et al.* 2017](#); [Charles *et al.* 2025](#)). While steps have been taken to safeguard affordability and integrate co-creative participatory approaches, these initiatives remain fragile ([Devenish & Lockwood 2024](#)).

Accordingly, scholars emphasise the need to effectively implement energy justice, conceptualising it normatively, predominantly through the three tenets of distributive, procedural and recognition justice ([Jenkins *et al.* 2016](#); [McCauley *et al.* 2013](#); [Sovacool & Dworkin 2015](#)), or as a context-sensitive concept shaped by scale, local conditions and surrounding ecosystems ([Tarasova 2024](#); [Wood *et al.* 2024](#)). Closely interconnected, these three dimensions emphasise a fair distribution of benefits and burdens, transparent and inclusive procedures and decision-making processes

that recognise residents' diverse needs and vulnerabilities. This perspective underpins just urban transitions, allowing cities to address inequalities in access to efficient housing, energy and services, with critical considerations of the sociocultural implications of green and low-carbon 'solutions' (Dodman 2022; Hughes & Hoffmann 2020). Within this framework, Shejale et al. (2025) position procedural justice as a gateway for advancing energy justice, enabling redistribution and recognition by addressing structural conditions of inequity, often rooted in institutionalised hierarchies that prevent certain groups from participating as full peers in social life (Fraser 2008; Fraser & Honneth 2003). Although neighbourhood-based experimentation has shown promise in fostering inclusive decision-making and learning among residents, municipalities and market actors (Hofman et al. 2021), and ULLs are recognised as sociotechnical intermediaries for justice by improving households' living conditions and energy affordability (Bouzarovski et al. 2023), there is a limited understanding of how ULLs can operationalise procedural justice in housing energy renovations.

This study examines the role of ULLs in energy retrofit and transition by relating them to the dimension of procedural justice. The initial set-up and diagnostic phases of four Dutch urban energy living labs (ELLs) are investigated in energy-poor neighbourhoods of Rotterdam, Amsterdam, Gemert and Nijmegen. The research question is:

How do the early implementation phases of ELLs support the co-creation of justice in housing energy retrofit and transition projects in vulnerable Dutch neighbourhoods?

The analysis thus examines how ELLs, as processes of interaction, intersect with procedural justice concerns by facilitating actors, reflections, and collaborations that support residents' representation and inclusion. Yet it refrains from prescribing what is 'procedurally just', without direct validation from residents.

The study adopts the terminology of *energy living labs* to refer to a specific subset of ULLs intentionally established to co-address urban issues related to local energy transition and building renovation initiatives, particularly at the neighbourhood and building scales. This choice aligns with the Dutch context of the study, where these ULLs were explicitly created within ongoing neighbour-level transition programmes linked to municipal natural gas phase-out plans, making their energy focus both defining and operational. Their scope includes raising awareness of energy issues, aligning institutional strategies with residents' everyday (energy) practices, and experimenting with governance arrangements and project implementation.

The article is structured as follows. Section 2 presents a theoretical framework that positions procedural justice as locally shaped through process learning. Section 3 details the methodological approach, analytical framework and contextual background of the case studies in which the ELLs are ongoing at the time of writing. Section 4 presents the findings. Section 5 discusses how ELLs' early phases contribute to procedural justice. Section 6 concludes with practical and research implications.

2. LOCALLY SHAPED PROCEDURAL JUSTICE: THE ROLE OF PROCESS LEARNING

Procedural justice in urban transitions highlights the importance of local participation in decision-making, transparent information-sharing, and meaningful opportunities for residents to influence outcomes (Hughes & Hoffmann 2020; Suboticki et al. 2023). Perceptions of process fairness profoundly shape their acceptance of outcomes, even when unfavourable (Axon & Morrissey 2020; Walker & Devine-Wright 2008). While ULLs can foster community trust and engagement, participation often remains symbolic rather than substantive (Liedtke et al. 2015; Soikkeli et al. 2023; Voytenko et al. 2016). This challenge is amplified in vulnerable neighbourhoods, where daily struggles like socio-economic hardship, health issues, energy-inefficient housing and low institutional trust complicate an active involvement in energy transition (Snep et al. 2023). Energy justice thus emerges not as a static concept but as a process of co-construction of local meanings among residents, policymakers and practitioners (Rasch & Köhne 2017). This perspective

foregrounds issues of representation, recognition and structural inequity (Shejale et al. 2025) in institutional decision-making, reciprocally linking procedural justice to the other justice dimensions (Broers et al. 2022).

The experimental action of ULLs, activating spaces for dialogue, co-creation and stakeholder engagement, facilitates translating locally grounded insights into broader systemic transitions (von Wirth et al. 2019). This process relies on collective forms of reflexive learning, enabling actors to iteratively question assumptions and adapt institutional practices (Schön 1984; von Wirth et al. 2019). This aligns with the notion of process learning (Evans et al. 2021): a layered and adaptive form of urban learning that experiments with new collaborative modes, evolving stakeholders' roles, and reflexive evaluations. It builds on individual and group-level social learning, generated through dialogue and mutual sense-making among diverse stakeholders, including residents, which, if institutionalised, can evolve to organisational and interorganisational learning. These institutionalised learnings drive local sustainability transitions, by prompting organisations to adjust internal and network-related routines, strategies and responsibilities, ultimately enabling systemic transformations (Costa et al. 2022; Evans et al. 2021; Stam et al. 2023). Within this process, researchers in ULLs act as catalysts of this mutual learning rather than passive observers. They design 'spaces of encounter' between formal expertise and situated knowledge, thereby fostering collective experimentation and learning for complex urban challenges (Franz 2015).

This study thus argues that purposive experimentations, grounded in iterative process learning-by-doing and doing-by-learning (von Wirth et al. 2019), are integral to advancing procedural justice and its interconnected dimensions of energy justice. Accordingly, it critically positions early-stage ELLs within this process, examining how justice can be co-created through researcher-facilitated learning with practitioners and residents.

3. METHODS

3.1 METHODOLOGICAL APPROACH

The analysis focuses on four Dutch ULL cases from the Just PREPARE research project (<https://justprepare.nl/>), hereafter referred to as ELLs, as context-specific experiments in neighbourhood-scale housing energy transitions. The study adopts a comparative case study methodology embedded in an action research project, drawing on semi-structured interviews and field notes from ELLs' group sessions. The comparative approach emphasises a processual and relational analysis, tracing dynamics across multiple contexts and analytical scales to identify patterns that enable theoretical transferability (Bartlett & Vavrus 2017). Investigating multiple cases enables systematic comparisons and data richness, providing a holistic understanding of social phenomena within their specific contexts (Gustafsson 2017) and supporting evidence-based strategies and actionable, context-sensitive interventions. The action research orientation reflects the situational inquiry of ULLs, where researchers actively participate to address local practical problems (Chevalier 2019). It aims to explain and improve systems by producing knowledge relevant to both theory and practice, through collaborative processes of joint problem identification, analysis, action and reflection (Collatto et al. 2018).

3.2 CASE SELECTION AND DATA COLLECTION METHODS

The study focuses on four ELLs implemented in Amsterdam Zuidoost, Rotterdam Bospolder-Tussendijken (BoTu), Nijmegen-Dukenburg, and Gemert. These cases were purposely selected in line with the Just PREPARE project's focus on Dutch vulnerable neighbourhoods undergoing sustainable heating transition and/or housing energy renovation, for which dedicated ULLs were established to engage local communities and institutions in advancing a just transition. Inclusion criteria were: a) programme readiness (ongoing or imminent heating transition/energy renovation); b) socio-spatial vulnerability (low-income households, inefficient housing stock, energy poverty); c) institutional access and community initiatives (commitment of municipal and housing actors to collaborate, and active resident organisations); and d) variation (diversity in built fabric, tenure mix and governance arrangements). All cases meet these criteria, albeit with varying salience.

As resident and stakeholder engagement is tailored to local conditions (e.g. ELL session formats, thematic agendas), research approaches and interaction strategies differ across sites. Variation is inherent to participatory transition arenas and is treated as a source of analytical insight, rather than inconsistency (Lukkariinen et al. 2025). Comparability is thus constructed through a common focus on ELLs' initial phases, tracing procedural justice dynamics across diverse research–practice settings.

Table 1 specifies data collection methods and sources, differentiating primary materials analysed in this study from supplementary datasets from parallel studies, used to contextualise neighbourhoods and local energy transitions. For transparency and traceability, anonymised reference codes were assigned to interviews and field notes (Table S1 in the supplemental data online) cited in the findings.

Researcher positionality differed across cases: Amsterdam and Rotterdam were primarily covered by authors DR and CL, and Gemert and Nijmegen by authors SVW and PDK. As Dutch was the working language, authors CL, SVW and PDK, who are Dutch speakers, participated in ELL sessions as observers/occasional co-facilitators, whereas author DR remained non-embedded and led the cross-case synthesis without direct involvement in sessions. While embeddedness improves access and contextual understanding, it also risks role-related bias. Incorporating external analysts mitigated this risk through analytic distance and an embedded external double-coding approach (Ortloff et al. 2023). Interpretative claims were reviewed by all researchers, with discrepancies resolved through negotiated consensus. Field notes, taken during and after sessions without a formal template, combine descriptive chronologies with reflexive commentary. Dutch excerpts were translated into English and back-checked by bilingual authors.

Table 1: Data collection methods, sources, and outputs for the four ELLs

METHODS AND DATA SOURCE	CASES AND VOLUME	COLLECTION TIMEFRAME	MATERIAL/OUTPUTS
<i>Primary data sources (directly analysed for this study)</i>			
Participants' observations in ELL sessions – field notes.	Rotterdam 10 sessions, Amsterdam 7, Gemert 15; Nijmegen 12.	October 2023–April 2025.	Typed notes with reflexive memos; selected artefacts (agendas/slides).
Semi-structured interviews with ELLs' facilitators.	5 interviews (≥1 per lab); 30–60 min., online and in person.	March–April 2025.	Audio-recorded; verbatim transcripts (Teams/Atrain); anonymised.
<i>Supplementary/contextual sources (used for case description; not systematically analysed)</i>			
Interviews with local stakeholders.	Rotterdam 22; Amsterdam 9; Gemert 7.	March–June 2023, November 2024–April 2025.	Audio-recorded; verbatim transcripts; anonymised.
Fieldwork and desk review.	All cases.	2023–2025.	Project reports; typed notes.

3.3 ANALYTICAL FRAMEWORK AND DATA ANALYSIS

The empirical data were analysed through an abductive, thematic approach combining inductive coding with a deductive overlay. The deductive frame draws on established ULL methodology guidelines, which outline key ULL components and levels (ENoLL et al. 2025; Zalokar et al. 2021), and on procedural justice considerations, constituting an overarching theme tracked across cases' dynamics. The semi-structured interviews with ELLs' facilitators offered insights into ELL structures, local challenges and stakeholders' dynamics, further enriched by the authors' reflective observations from direct involvement in ELLs' activities.

The analysis resulted in three thematic clusters, representing aggregated dimensions derived from synthesising theoretical insights with inductive coding. This analytical framework reflects the LLs' multiscale logic (Schuurman 2015), which provides analytical differentiation between macro (organisational structure), meso (project), and micro (user activity) levels. Accordingly, the identified themes address both the strategic development of ELLs and their embeddedness within context-specific experimental settings and multistakeholder dynamics:

a) The first theme captures the temporal trajectory of ELLs and their initiation and early-stage evolution. As both the research and the local housing energy transition initiatives are ongoing, the analysis is limited to initial set-up and diagnostic activities. Although LLs vary in structure, previous studies typically outline three to five key phases: i) preparation and definition, including problem framing and scoping; ii) ideation and co-creation, where solutions are collaboratively developed; and iii) evaluation, involving testing and refinement based on stakeholder feedback (Bridi et al. 2022; Kowaltowski et al. 2024; Liedtke et al. 2015). This study does not address the co-creation of interdisciplinary solutions, as these are planned for later phases of the research project.

The thematic clusters b) stakeholder constellations and collaboration dynamics and c) ELLs as interface for local energy and housing issues also allow situating the ELLs within the ULL framing provided by the quintuple helix model (Almeida & Deutsch 2025; Carayannis et al. 2018). The multifaceted interactions between citizens, industry, knowledge institutions and municipalities (corresponding to the first four helices) were examined for their implications for energy-related practices and research. This underscores research embeddedness in real-world energy transition contexts, while countering extractivist approaches through reflexivity, mutual learning, and knowledge co-production (Glassman & Erdem 2014).

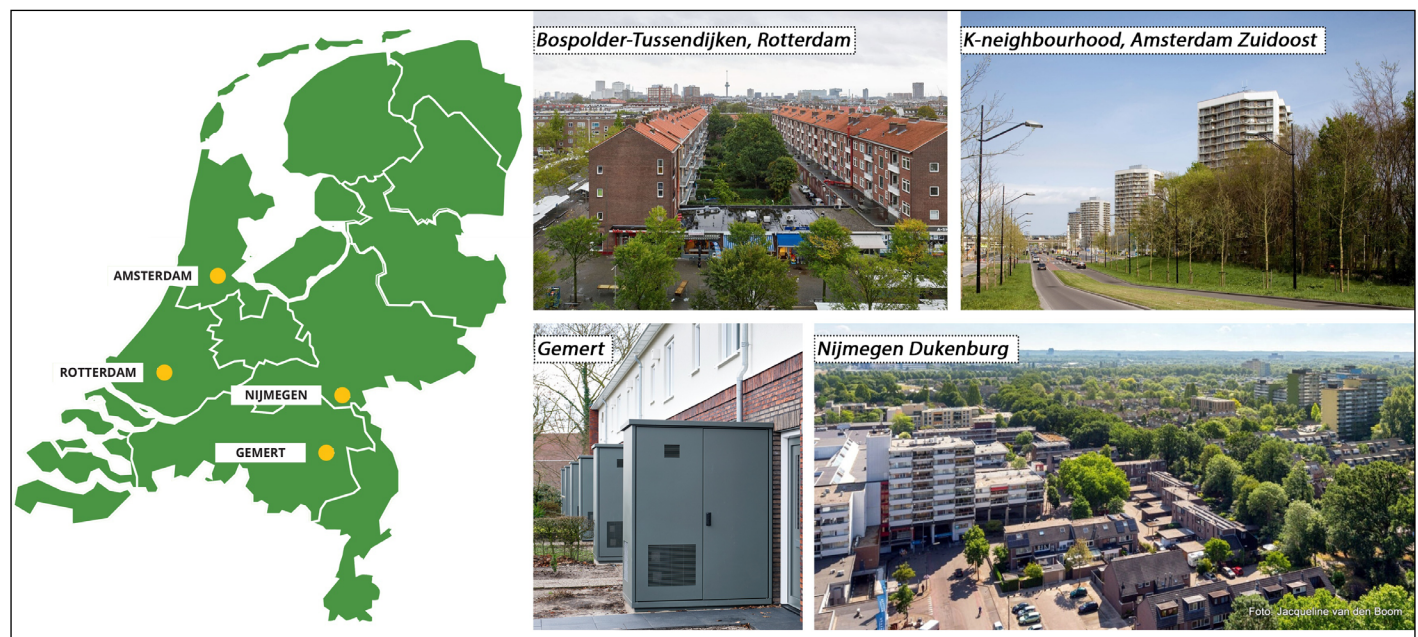
Theme c), in turn, engages more directly with the fifth dimension of the natural environment, following Almeida and Deutsch's (2025) reading, in which it is reflected in the sustainability and liveability concerns of transitioning urban ecosystems. From this perspective, the analysis calls for critical reflection on ELLs' role in mediating this process.

3.4 CONTEXTUALISING THE CASE STUDIES

The four case studies represent the Just PREPARE project's primary empirical sites (Figure 1), with the ELLs combining practical interventions with action research. Table 2 summarises the sociocultural framing of each case, alongside residential typologies and sustainable transformations. Shared vulnerabilities coexist alongside contextual differences, informing the development of scalable, justice-oriented strategies applicable to other neighbourhoods and municipalities.

Figure 1: The four Dutch case studies undergoing neighbourhood energy transition and renovation.

Sources: Rotterdam: NRC (<https://www.nrc.nl/nieuws/2019/10/03/het-wilde-westen-van-rotterdam-moet-straks-klimaatneutraal-wokken-a3975580>); Amsterdam: K-flats-Arcam (<https://arcam.nl/architectuur-gids/k-flats/>); Gemert: Goed Wonen Gemert-Nathan (<https://www.nathan.nl/onze-projecten/goed-wonen-gemert>); Nijmegen: J. vd Boom 'Ontwerpbestemmingsplan Nijmegen-Dukenburg 2021'-de Dukenburg (<https://dedukenburger.nl/ontwerpbestemmingsplan-nijmegen-dukenburg-2021/>).



	BOTU-ROTTERDAM	K-NEIGHBOURHOOD AMSTERDAM ZUIDOOST	GEMERT	NIJMEGEN- DUKENBURG
Historical and sociocultural context	Early 20th-century harbour district, highly working-class area marked by unemployment, low income and low education, yet sustained by strong networks and activism. Designated Resilient BoTu 2028 renewal pilot.	1960s modernist high-rise district redeveloped into low/mid-rise mixed housing; highly multicultural with strong local identity.	Historic village in rural North Brabant, with medieval core and post-WWII residential expansion. Traditionally agriculture-based, now facing demographic ageing and economic transition.	1960s–1970s modernist suburb; from middle- to lower-income; ageing housing; disinvestment; multicultural, older residents; unemployment, low education, weak cohesion, institutional distrust.
Building types and performance	Dense pre- and post-war multifamily housing, mostly uninsulated. Apartment blocks, terraced houses, and porch houses. Predominantly energy labels C–G.	Mix of residential types: low-/high-rise and four social housing towers. Mostly post-2000, A–B rated yet underperforming; prefabricated concrete with little insulation.	Mix of post-war low-rise houses, small apartment blocks, and older farmhouses. Energy performance varies; many pre-1990 homes poorly insulated with outdated heating.	Mix of 1960s–1970s mid/high-rise blocks, row housing, and low-rise flats, mainly E–G labels. Renovated sections improved but remain substandard.
Ownership	Predominantly social housing, limited private ownership.	Mix social housing, private rent and owner-occupied.	Mainly owner-occupied housing with some social rentals managed by the local social Housing association (SHA).	Primarily social housing (three SHAs), with pockets of owner-occupied homes.
Energy transition and renovation strategy	BoTu Energy District: gas-free by 2035 through district heating, insulation, and envelope upgrades, coupled with social initiatives.	District heating connections through the Warmte Amsterdam programme. Social housing partial envelope insulation.	Street-based pilots for sustainable renovation, renewable energy integration, and circular building for over a decade.	Pilot district for natural gas phase-out, expanding district heating network, and hybrid solutions.
Energy (in)justices	Energy-inefficient housing, energy poverty. Justice claims supported through multilingual outreach, co-creation and affordable housing.	Energy-inefficient housing, high energy bills, limited participation, institutional neglect.	Energy-inefficient housing, spread out pockets of low-income households with systemic vulnerabilities, unaffordable housing, distrust, stigmas, ageing population, and transport poverty.	Ageing social housing burdens elderly and low-income households. Decision monopoly of SHAs/municipality. Digital literacy and language barriers, historical underrepresentation in urban renewal processes.

Table 2: Description of the local contexts where the ELLs were implemented

Note: See extended version in Table S2 in the supplemental data online.

4. RESULTS

The analysis is presented through three key themes that situate ELLs in relation to procedural justice, illustrating how dynamics across cases foster or challenge trust, multistakeholder collaboration, and connections between institutional and research processes and neighbourhood realities.

4.1 INITIATION AND EVOLUTION OF THE ELLS

The four ELLs were initiated under the mediation of the Just Prepare research project, aligned with its timeframe but with different starting conditions reflecting variations in neighbourhood dynamics and institutions' cooperation (Figure 2).

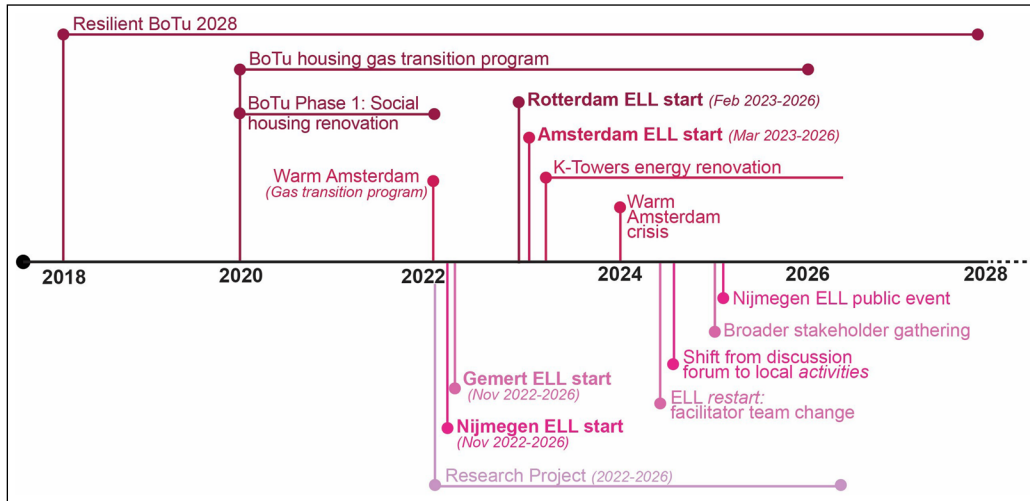


Figure 2: Initial development of the four ELLs within ongoing neighbourhood energy transition initiatives.

In Rotterdam BoTu, the ELL is embedded in two ongoing programmes: the municipal Resilient BoTu 2028, aimed at strengthening the community's social, economic and physical conditions, and the national Natural Gas-Free Districts, supporting municipalities in decarbonising neighbourhoods through local pilot projects. This institutional anchoring provided legitimacy, resources, and a shared framework, but also revealed its limits, as trust-building required patience and careful negotiation (INT-F1-2-A/R). These dynamics highlight procedural justice challenges to resident influence in decision-making within a highly institutionalised setting. Yet, with trust established, the ELL operates as a recognised platform integrated in the neighbourhood's actor network, structured around a co-developed 'learning calendar'.

By contrast, the Amsterdam ELL emerged in a fragmented setting. Its initial linkage with a prominent resident organisation dissolved owing to capacity constraints, leaving the lab without a clearly demarcated framework, operating on a more *ad hoc* basis, shaped by the district's fluid social and political conditions (INT-F1-2-A/R). Activities included workshops and thematic group discussions with municipal and housing representatives. While this adaptive approach reveals emergent priorities and enables flexible participation, it also causes fluctuations in scope (SES-A).

The Gemert ELL built on existing relationships within a rural care and well-being alliance. Local SHAs, already active in renovations and committed to the energy transition, sought to strengthen connections with knowledge institutes, which had been barely involved in the area (INT-F3GN). Conceived as a *praktijkleerwerkplaats* (practical learning workshop), or 'spark hub' for student-researcher collaboration on housing and care issues (SES-G), it was initially imagined as a physical hub with a cohesive group (INT-F3GN). Practical constraints shifted it into a flexible and open network-based model (INT-F5GN). Stakeholder turnover and limited continuity resulted in what participants described as a 'restart' of the ELL, prompting a re-evaluation of its purpose and composition, while fostering accessible and reflective forms of collaboration amid changing dynamics (INT-F3GN).

In Nijmegen, the ELL began without previous connections among local institutions, requiring new collaborations from the outset (INT-F3GN). Researchers pre-selected the Dukenburg district with a SHA, municipality, and social welfare organisation, already engaged in previous projects. However, finding suitable stakeholders took time: without established relationships, amid turnover and competing agendas, participation fluctuated, with some organisations often questioning the benefits of involvement (INT-F4N, SES-N). Over time, the ELL evolved from a discussion forum to a platform organising low-threshold activities to meet residents and (in)directly address energy issues, creating two levels of learning: how to engage residents so their voices were heard, and how organisations could collaborate more effectively (INT-F3GN, SES-N).

4.2 STAKEHOLDER CONSTELLATIONS AND COLLABORATION DYNAMICS

All four ELLs engaged similar stakeholders (Table 3), with participation levels varying but consistently including housing and energy actors alongside resident-oriented social organisations.

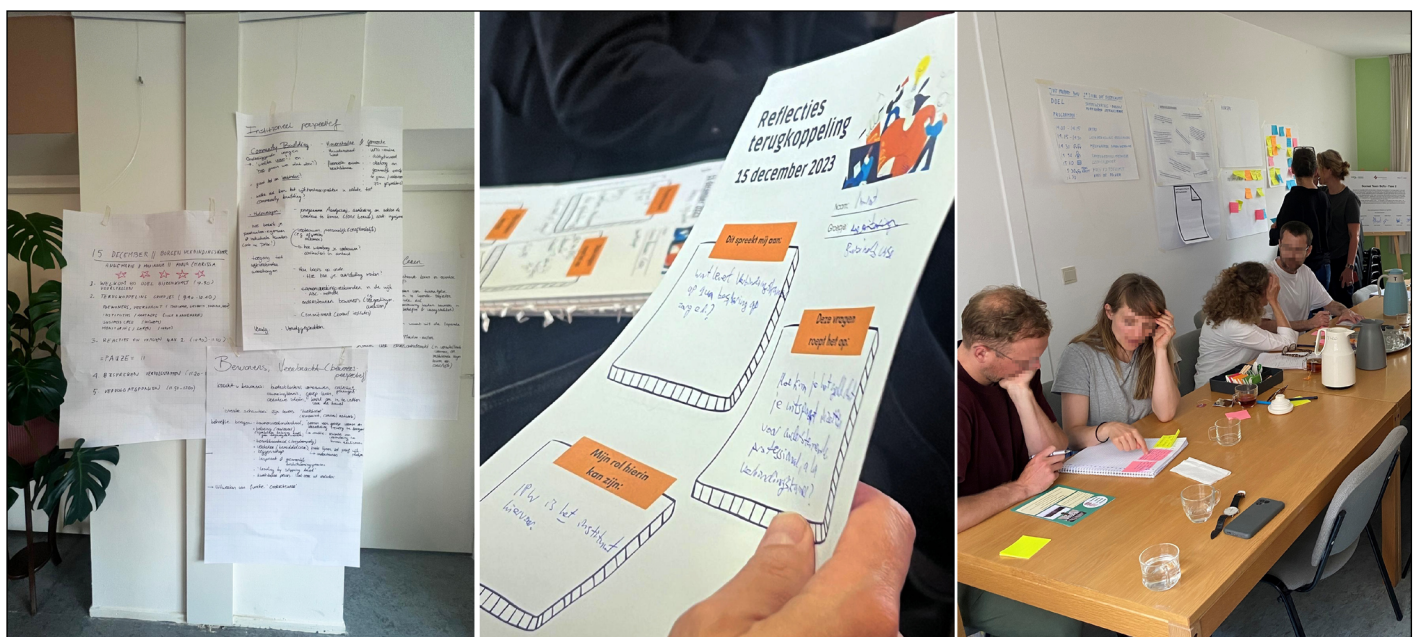
BOTU-ROTTERDAM	AMSTERDAM ZUIDOOST	GEMERT	NIJMEGEN-DUKENBURG
- Facilitators: organisers/ trust-builders/ connectors (practical role). - Municipality: main funder and active actor in transition programme - SHAs: active implementation actor - Researchers: knowledge-producer/ transfer (analytical role) - Energy company representative - Social organisations (residents indirectly involved)	- Facilitators: (practical role) flexible/ad hoc approach - Municipality: engaged but with tensions - SHA focused on justice concerns - Researchers: (analytical role) - Local community group	- Facilitators: (practical role) - SHA: consistent actor - Municipality: supportive in initiating/organising engagement - Residents: indirectly involved - Researchers (analytical role) - Three social organisations supporting vulnerable groups - Energy coaches	- Facilitators: (practical role, with turnover) - Municipality: involved in planning but less proactive - Three SHA: variably engaged, facing resident resistance - Social organisations - Residents: active in events, some in core meetings - Researchers (analytical role) - Occasional network/ educational participants

Table 3: Key stakeholders involved in the ELLs

Collaboration dynamics were shaped by both the types of ELLs' activities and the strength of local networks. In Rotterdam, a 'close-knit' group developed solid relationships, with the municipality playing a strong leading role both in the energy project and the ELL sessions. A key ambition was to reflect on the social impact of local collaborations involving formal and informal institutions (INT-F1-2-A/R). Despite the intention of having sociotechnical expertise at the table, the collective need was inherently social. Stakeholders recognised that moving beyond formal responsibilities enabled cross-role interactions, fostering integrated approaches and collective ownership of the transition (Manktelow et al. 2023). For the SHA and the energy company, a recurring concern was demonstrating the social value of neighbourhood engagement to back offices, which typically demand quantifiable results (SES-R). Early trust-building by facilitators eased researchers' entry and acceptance, with the ELL providing a softer landing in the neighbourhood (INT-F1-2-A/R). Researchers, in turn, facilitated a 'learning calendar' to collectively explore questions on collaboration, energy justice and the transferability of successful practices in other contexts, linking on-the-ground activities with organisational learning (see Figure 3).

Figure 3: Workshop setting and outputs from Rotterdam ELL sessions.

Note: Collective discussions focused on residents' resilience, institutional perspectives, business case development and monitoring/learning.



Collaboration in the Amsterdam ELL unfolded through a fluid approach, as researchers continually sought alternative local actors and modes of engagement. Inconsistent participation prevented the formation of a cohesive multistakeholder group, reflecting the fragmented nature of energy governance in Amsterdam Zuidoost (SES-A). The lab repeatedly realigned after failed pathways, ultimately turning to SHAs as key actors. While this proved the value of ELL's adaptive capacity, it also underscores the complexity of pursuing a just transition in a large district with unstable dynamics (INT-F1-2-A/R). Stakeholders experienced how the absence of a strong collaborative platform or long-term shared vision hindered consistent planning and meaningful resident participation. Meetings and workshops were often improvised, yet researchers' mediation created space for explicit discussions of energy justice, though this seldom translated into concrete neighbourhood actions. Tensions between local social organisations and the municipality further revealed how contextual and political dynamics shape collaboration, residents' representations, and the perceived urgency of action research (SES-A).

Gemert ELL adopted a core-shell structure: researchers, municipality, and the SHA forming the core, while technical staff, energy coaches and social professionals joined depending on the session's focus (INT-F5G). Collaboration developed slowly and required several restarts owing to personnel changes, but the small core group provided stability, even though they prioritised practical, day-to-day issues rather than larger strategic questions (INT-F6G). Sessions with shell actors occasionally disrupted group dynamics and trust, entrenching thinking within one's profession instead of addressing transcending issues together (INT-F3GN). Nevertheless, meetings were valued by stakeholders as spaces for reflection and 'sparring', with complementary perspectives between social and technical advisers (INT-F6G). By attending most ELL sessions, researchers connected with local professionals and community histories, values and concerns, while also using the venue to share preliminary findings. However, tensions emerge when interests misalign: when professionals seek prescriptive, quantitative outputs to address day-to-day issues or focus narrowly on resident behaviour while overlooking systemic factors. Such dynamics hinder the introduction of perspectives that contextualise resident (energy) behaviour or question professional assumptions, normative standards around heating, and institutional practices. The ELL thus supported mediation by making divergences explicit and opening them up for collective reflection (SES-G).

Nijmegen's dynamics were more outward-oriented, with the ELL prioritising neighbourhood activities linked to residents' values (health, nature, affordability) over structured reflective sessions. Its network expanded through snowballing, engaging smaller organisations, residents' groups, local energy coaches and fixing services. Discussion depth and continuity were challenged as professionals frequently joined and left, with SHAs unevenly engaged, often preferring to be approached with fully formed plans rather than co-developing ideas (INT-F4N). The social work organisation became more active once the local energy transition turned contentious, and as the ELL shifted on organising activities. This pragmatic orientation is appreciated for offering residents relational events, facilitating engagement with daily concerns; however, it limits deeper reflections or cross-organisational exchange (INT-F3GN). As in the other cases, the ELL brought researchers closer to lived realities. A PhD researcher initially spent one day a week at the municipal energy consultation service in the local shopping centre, gaining insights into residents' concerns and district dynamics as people stopped by spontaneously during shopping trips. The subsequent closure of this location raised reflections on how being physically there makes it easier to connect to the neighbourhood and share energy information, while also emphasising the researcher's position as an 'outsider' (SES-N). More broadly, researchers gained a deeper appreciation of the complexity of conducting research on politically sensitive transitions, where navigating tensions requires careful coordination and trust-building.

4.3 ELLS AS INTERFACE FOR LOCAL ENERGY AND HOUSING ISSUES

The ELLs were established in contexts with local commitment to energy renovation and transition, where projects were either already underway or planned. Their shared ambition to support these transitions by fostering resident acceptance and integrating their needs provides cohesion and orientation for ELL activities. Yet the Amsterdam case illustrates how the crisis of a 'unifying big energy project', combined with the area's scale, challenged inclusive participation (INT-F1-2-A/R).

Across cases, the ELLs opened channels for direct and indirect engagement with neighbourhood realities and for justice-oriented discussions, sensitising stakeholders to local needs and to collaboration values. Where the energy transition project was perceived as successful, as in BoTu, the ELL focused on understanding how and why the coalition functioned effectively. Although its pilot character, high costs and context-specificity limit replicability in other vulnerable settings, certain collaborative practices can be effectively incorporated into organisational routines and transferred elsewhere (INT-F1-2-A/R). To this end, BoTu stakeholders co-developed a learning calendar addressing both the layered sociotechnical impacts of renovation and ways to sustain collaboration beyond the project's lifespan. They emphasise both structural supports (e.g. consistent neighbourhood meetings, sufficient funding) and interpersonal qualities such as empathy and role flexibility, which help hold the coalition together and advance the energy project on schedule (SES-R). A central challenge for the ELL was reconciling municipal decarbonisation objectives with residents' everyday concerns, such as mould and safety. Stakeholder stress 'meeting people where they are', noting that resolving immediate issues, such as housing maintenance or billing problems, contributes to broader impacts, including long-term trust and meaningful engagement (INT-F1-2-A/R, SES-R).

As in Rotterdam, where bilingual energy coaches and the local social organisations played a strategic role in reaching residents 'behind the front door', the Gemert and Nijmegen ELLs relied on mapping exercises to gain a nuanced understanding of the local context (see Figure 4). These exercises combined quantitative data, such as energy labels, income levels and housing typologies, with the situated knowledge of professionals from the social domain, SHAs and municipal planning teams. Beyond producing an integrated picture of technical and social conditions, the process is generative: it allows participants to exchange perspectives, identify suitable locations for household-level fieldwork, and highlight areas of diversity (e.g. social housing alongside low-income homeowners, mixed generations, and culturally diverse residents living in similar apartment blocks) (SES-G, SES-N).

Figure 4: Neighbourhood sociotechnical values maps developed through Gemert and Nijmegen-Dukenburg ELLs.



In Gemert, ELL researchers also collaborated with a municipal initiative that provided small-scale energy fixes to low-income households, allowing researchers to accompany mechanics on home visits and gain valuable insight into residents' everyday energy practices (SES-G). Similarly, the Nijmegen ELL organised low-threshold activities (in)directly related to the energy transition, with careful attention to location, themes, and participating organisations (see Figure 5). ELL stakeholders in Nijmegen and BoTu work with asset-based community development (Kretzmann & McKnight 1996), which assumes that activities should be rooted in the neighbourhood's organisational capacity, needs and interests. So, rather than starting from the energy transition, a theme often distant from residents' priorities, the ELL built on existing initiatives and concerns such as love for nature, health, social cohesion and living costs.



Figure 5: The *Warme Wintermiddag* (warm winter afternoon) organised in the Lankforst neighbourhood of Dukenburg (February 2025).

Note: The event combined informal gatherings with opportunities to meet energy coaches, join a guided ecology walk and raise concerns about the heating transition. The top-right image shows neighbours discussing their plan for a small neighbourhood improvement.

However, discussions remain on whether the ELL risks projecting its own values and interpretations onto residents, and on how the absence of governance institutions limits the extent to which residents' voices influence decision-making processes beyond the ELL (INT-F4N).

In parallel with practical outings, reflective discussions unfolded across the cases. As examples, Amsterdam ELL organised a thematic group explicitly focusing on energy justice. Starting with its normative conceptualisation of distributional, procedural and recognition justice allowed stakeholders to collectively explore their situated meanings in respective context(s), developing a shared understanding of the concept before moving to practical implications and interventions (INT-F1-2-A/R). An initial normative framing of energy justice thus appears a necessary and strategic step towards meaningful operationalisation of justice-in-practice in urban energy transitions (Ricci et al. 2025).

In Gemert sessions, recurring themes of tenant ownership and participation indirectly bring justice issues to the table. Stakeholders tended to frame ownership as tenants taking initiative in the energy transition. However, only idealised or large-scale forms of ownership and participation appear valued; smaller, practical actions by tenants, such as modification to internal partition walls or turning off the noisy ventilation system, are often overlooked as a sign of ownership. Discussions also raised questions of resource distribution (e.g. energy fixers, subsidies for efficient appliances), who should be prioritised for support, and whether professionals should assume full responsibility or encourage self-reliance. Additional concerns include privacy regulations limiting information-sharing and interorganisational exchanges (e.g. energy coaches unable to report social issues), the rising cost of solar panels and residents' reluctance to adopt them, and whether the ELL genuinely fosters a just transition or risks remaining a symbolic forum (SES-G).

The empirical analysis provides significant findings into the dynamics that the early phases of ELL implementation have on the operationalisation of procedural justice in energy transition and renovation processes in vulnerable Dutch neighbourhoods. The structures and goals of the ELLs reflect core ULL values, such as multistakeholder involvement and authentic everyday settings (ENoLL et al. 2025). The alignment with the quintuple helix model, including academia, industry, government, civil society and the natural (and built) environment, highlights how ELLs foster systemic integration of sustainability and social inclusion goals through mediation mechanisms and practice-embedded process learning.

The following subsections present key justice-related implications arising from the ELLs' analysis.

5.1 SUPPORTING PROCEDURAL JUSTICE THROUGH INNOVATION AND LEARNING

In all four cases, the ELLs operate predominantly as social laboratories, focusing on multiple complex energy transition challenges: actor interests, housing quality, energy practices and vulnerable group involvement. Unlike conventional, technology-driven LLs that prioritise product and service development, the ELLs emphasise socio-spatial considerations and collective perspectives, thereby advancing *social innovation* (Franz 2015; Hoppe & De Vries 2019; Scholl & Kemp 2016). The innovation of the ELLs lies in complementing local housing decarbonisation plans and projects with collaborative networks committed to community-sensitive governance (Blezer et al. 2024) and energy justice, echoing Almeida and Deutsch's (2025) argument that ULLs must embed ecological and social dimensions within urban innovation. This integration not only supports just transitions (Sovacool et al. 2023) but also helps overcome renovation bottlenecks in technical planning through trust-building, stakeholder information exchange and context-sensitive understanding of residents' building practices (Prieto et al. 2023).

The ELLs effectively served as arenas for reflexive self-evaluation, whether individual or collective. Through the regularity of sessions, self-evaluation evolves into iterative process learning (Bridi et al. 2022; Voytenko et al. 2016), making continuity in participation and turnover critical factors in ELL implementation. In particular, the Rotterdam ELL was deliberately set up to learn and evaluate how collective visions could inform local energy transition projects, with stakeholders regularly revisiting their action methods to better align them with neighbourhood dynamics. This process learning, situated and experiential, underpins more transformative learning outcomes (Evans et al. 2021; von Wirth et al. 2019), at the organisational and interorganisational scale, by stimulating 'deeper' or 'higher-loop' learning with continuous reflection on assumptions, power dynamics, and established strategies (Costa et al. 2022; Stenberg 2018). Activating such critical reflections in professionals helps counter single-minded views of residents'(energy) practices detached from their social contextual dynamics (Raven et al. 2021).

ELLs' session themes further demonstrate the importance of making energy justice tangible. By addressing its dimensions explicitly or implicitly (e.g. Amsterdam, Gemert), energy justice emerges not as a predefined normative ideal but as a situated concept, embodied in practice and refined in relation to local realities. In this way, ELLs help to keep energy justice 'in the loop', fostering attentiveness and sensitivity to how it is continuously made and remade across settings, rather than assumed as fixed or universal application.

5.1.1 Involving technical expertise for effective socially sensitive processes and solutions

While ELLs' focus on social dimensions operated as a learning bridge across organisational levels – from neighbourhood-based practitioners to strategic-institutional stakeholders – the absence of technical professionals limited their potential for meaningful sociotechnical integration. This missed the opportunity to address mismatches between community needs and technical decisions underlying housing renovations or energy infrastructures (Hamdan et al. 2021) by bringing technical professionals closer to residents' everyday practices and reflective discussions. Such engagement could foster a shared understanding that technologies are not neutral tools but embedded into, and often shaped by, institutional contexts, social dynamics and lived experiences (de Feijter &

van Vliet 2021). When renovation strategies are co-created with resident input, acceptance and effective use of new technologies can improve, contributing to energy consumption reductions (Guerra-Santin et al. 2017). Instances such as bypassing residents' concerns or their agency in spatial and energy practices, as seen in the Gemert case, illustrate the challenges of integrating socially innovative approaches into renovation process (Kowaltowski et al. 2024). However, the analysis demonstrates how the initial ELLs' phases contribute to surfacing these issues of residents' representation, positioning stakeholders before questions that constitute key barriers to inclusive processes, thereby helping to prevent the perpetuation of unjust procedures. Future research should further examine what hinders effective sociotechnical transfer and how it might be better facilitated.

5.2 ELLS AS RELATIONAL ARENAS FOR ENABLING PARTICIPATION

In most cases, the ELLs set-up fostered a trusted network of municipalities, practitioners, researchers, and residents or their representatives. Despite limited direct resident participation in sessions, the involvement of social organisations safeguards the integration of local perspectives, supporting ELLs as intermediaries (Bouzarovski et al. 2023) while easing participation burdens for vulnerable groups (Gillard et al. 2017). This relational function reflects procedural justice by promoting residents' visibility and co-creation of shared values and responsibilities (Bouzarovski et al. 2023; Bridi et al. 2022; Shejale et al. 2025). It lays foundations for reciprocal practice–practice, practice–science and institutional–lived realities support. Informal gatherings in Nijmegen and home visits in Gemert enabled direct interactions with residents in their sphere of proximity and daily life, while Rotterdam sessions on social impact stressed the value of cross-level and interdisciplinary collaboration.

The empirical analysis remains limited in tracing whether these relational dynamics and the interorganisational learning they foster effectively translate into equitable and inclusive actions in energy renovation practices. Given the multifaceted nature of these processes in vulnerable contexts (Tozer et al. 2023), parallel validations and monitoring are required.

'Creating a good setting for participation' is confirmed as essential for operationalising procedural justice and sustaining it throughout the process (Ricci et al. 2025). An effective strategy was to connect the ELLs to neighbourhoods with active stakeholders and initiatives rather than starting from a blank slate. This approach encourages participation through informal, spontaneous interactions rather than imposing it. The ELLs deliberately started with relationship-building and careful navigation of tensions, ensuring fairness and transparency in process initiation. The Amsterdam ELL, despite similar intent, demonstrated the challenges of achieving meaningful engagement in an extensive district lacking a cohesive governance structure and institutional stability (see Van Breugel et al. forthcoming). This underscores the critical role of spatial scale (Voytenko et al. 2016), suggesting that dedicated, project-scale ELL can usefully complement broader district-level ULLs in supporting vulnerable residents with technical choices, energy- and comfort-related issues. In this regard, the timing of ELL set-up also emerges as relevant: in all analysed cases, ELLs were established either after or in parallel with the implementation of energy-efficiency measures, rather than during the early decision-making phases, limiting the capacity of residents' inputs to shape core decisions. This risks shifting participation towards acceptance of predefined solutions than their co-creation (Bridi et al. 2022). Nonetheless, the four cases show that, even if ELLs appear 'late', they can still foster *process learning* to support ongoing or future interventions, as seen in Rotterdam ELL. However, critical reflections are needed, as urban experiments often face the pilot paradox (Metze 2023): their value creation and activities frequently remain confined to (research) project boundaries/timeframes, hindering long-term impact.

5.2.1 Rethinking research and professional roles

Professionals and researchers engaged through ELLs in more experimental and flexible modes of working, 'doing' transition (research) and governing, enabling greater responsiveness to emergent (social) sustainability issues (Herth et al. 2024; Kronsell & Mukhtar-Landgren 2018). In this sense,

ELLS function as liminal spaces where transdisciplinary science and practice converge (Blezer et al. 2024; Herth et al. 2024). Bringing institutional actors, such as energy companies and SHAs, out of the office and into the neighbourhood proved effective in advancing procedural justice within energy transitions, enhancing process transparency, cross-sector collaboration and valuing qualitative project performance. In ELLs researchers are expected to develop adaptive capacities and trust the process (Pentzold et al. 2023), embedding themselves in local networks for authentic interactions with residents and professionals. Their roles as boundary actors between sessions' discussions, resident interactions and knowledge translation can support professionals in capturing residents' perspectives and stimulate critical reflection on their own professional responsibilities in renovation strategies (Kowaltowski et al. 2024). In doing so, the research process itself becomes a vehicle for procedural justice, by connecting residents' lived experiences to organisational logics, opening up spaces for rethinking established routines and learning new bottom-up decision-making pathways (Blezer et al. 2024; Bouzarovski et al. 2023).

6. CONCLUSIONS

The study has introduced the ELL model as a specific form of ULLs that is focused on neighbourhood energy retrofit and transitions. It has analysed how early implementation phases contribute to advancing a just energy transition in four vulnerable Dutch neighbourhoods.

The research shows that, when ELLs are designed and facilitated as socially embedded and reflexive arenas, they have the potential to co-create procedural justice by fostering cross-level collaboration dynamics among local stakeholders, trust, and process learning. ELLs operate as relational spaces with adaptive capacities, enabling the design of resident-oriented (energy) initiatives and stimulating discussions addressing local needs, while also facilitating spontaneous interactions with residents. Such experimental approaches advance social-technical innovation, positively influencing inclusive and equitable decision-making in housing energy transition and renovation projects, particularly when residents' lived experiences and their energy-related concerns are made visible to challenge and rethink unjust organisational practices. From this analysis, a set of potential actionable strategies can be derived to help operationalise justice from the early phases of ELL implementation in support of housing energy transition and renovation interventions:

- Build collaborative networks aligned with existing neighbourhood dynamics.
- Invest in trust-building from early energy renovation decision-making phases.
- Promote sociotechnical integration through multidisciplinary relational arenas.
- Support spontaneous resident participation in everyday contexts.
- Value qualitative project performance and impacts on the field.
- Stimulate transformative learning capable of questioning established professionals' assumptions and practices.
- Govern collaboratively while remaining responsive to local needs.
- Facilitate collaboration between researchers and practitioners.
- Familiarise stakeholders with justice dimensions and shape them collectively to local realities.

This study thus contributes to identifying criteria that can enhance the transferability of context-sensitive participatory approaches and situated research, supporting an effective and just upscaling of energy transition and renovation projects. Future research could further explore these potential strategies, examining the capacities required during the subsequent ideation and evaluation phases of ELLs to sustain justice throughout the process.

ACKNOWLEDGEMENTS

This work is part of the Just Prepare project 'Putting REsident Practices And REsidential areas at the centre of a JUST and effective energy transition in underprivileged neighbourhoods' with file number KICH1.ED03.20.00 of the research programme NWO-KIC 'Energy Transition as a Socio-Technical Challenge', which is financed by the Dutch Research Council.

During the preparation of this work, the authors used ChatGPT and Grammarly to improve the clarity and cohesion of the English writing, as they are non-native English speakers. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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COMPETING INTERESTS

The authors have no competing interests to declare.

DATA ACCESSIBILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Data are not publicly available to protect the confidentiality of participants and ongoing project activities.

ETHICAL APPROVAL

The research project received ethical approval under a joint data controllership agreement among participating universities and research institutions. Additionally, data collection methods were approved by TU Delft's Human Research Ethics Committee. Participation was voluntary and all interview recordings and transcripts were obtained with participants' informed consent.

FUNDING

Funding was provided by the Dutch Research Council (NWO) under the JUST PREPARE project (file number KICH1.ED03.20.00) within the NWO-KIC programme 'Energy Transition as a Socio-Technical Challenge'.

SUPPLEMENTAL DATA

Supplemental data for this article can be accessed at: <https://doi.org/10.5334/bc.591.s1>

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TO CITE THIS ARTICLE:

Ricci, D., Leiwakabessy, C., van Wieringen, S., de Koning, P., & Konstantinou, T. (2025). Co-creating justice in housing energy transitions through energy living labs. *Buildings and Cities*, 6(1), pp. 747–766. DOI: <https://doi.org/10.5334/bc.591>

Submitted: 13 April 2025

Accepted: 14 September 2025

Published: 06 October 2025

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