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Living Labs in Social Housing Upgrades: Process, Challenges and Recommendations

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Abstract: Social housing (SH) upgrades involve multiple stakeholders with sometimes divergent requirements and needs. Collaboration and participative processes are essential to ensuring an appropriate value for users is delivered through social housing upgrades. Living Labs are user-centred initiatives where researchers, public and private partners, and users collaborate to develop innovative solutions in real-live environments. However, scarce research exists on how Living Labs may support the upgrading of social housing, and there is a need to explore what the challenges are that can be expected in this context. This paper discusses an integrative literature synthesis of housing upgrades developed within the context of Living Labs. Nine information-rich cases identified in the literature were chosen for in-depth examination. A living lab process was proposed based on the literature and activities and tools used in Living Labs were identified. From the challenges highlighted by existing studies, a series of recommendations to support the development of Living Labs in social housing upgrades was proposed. These should support Living Labs implementation initiatives in this specific context.

Keywords: Living Labs; social housing; upgrade; retrofit; collaboration

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Citation: Bridi, M.E.; Soliman-Junior, J.; Granja, A.D.; Tzortzopoulos, P.; Gomes, V.; Kowaltowski, D.C.C.K. Living Labs in Social Housing Upgrades: Process, Challenges and Recommendations. *Sustainability* **2022**, *14*, 2595. https://doi.org/10.3390/su14052595

Academic Editors: Grazia Napoli and Pierfrancesco De Paola

Received: 14 December 2021
Accepted: 18 February 2022
Published: 23 February 2022

1. Introduction

Social housing (SH) programmes aim to improve the living conditions of low-income households and reduce housing deficits. For many years, research questioned the quality as well as the sustainability performance of housing produced through SH programmes [1]. SH debates generally focus on new buildings, with scarce investigations focusing on upgrading or retrofitting the existing housing stock. In this paper, the term upgrading is used to refer to refurbishment, retrofit, or renovation to improve the well-being and sustainability performance of SH.

Upgrading the SH stock can have positive social, health, and financial impacts on low-income populations [2,3], whilst rendering broad economic and sustainability benefits. The sustainability challenges faced by countries around the world demand social, technological, and economic transformations that include housing. Energy and climate objectives are pressing and are convincing reasons for the upgrading of SH to elevate the housing stock to sustainable standards. To achieve global ecological sustainability, most developed countries adopt mandatory upgrading programmes with energy efficiency and greenhouse gas emission reduction goals that maintain good standards of environmental comfort and eliminate fuel poverty for users [4]. Focused improvements can ease the effects of inadequate housing in general by reducing social costs [5,6]. In developing countries, increasing the quality of social housing can alleviate housing deficit. Upgrading efforts should target the buildings themselves and their occupants' health and wellbeing [6,7].

SH upgrading is a multi-stakeholder venture [8]. Besides end-users, it involves housing associations, financers, construction companies, design professionals, among others, who have specific, and at times conflicting, needs and interests [9,10]. Collaborative work can support the achievement of diverse objectives set by a variety of stakeholders. However, it requires a shift from individual to shared engagements and foci [11], with often blurred multi-sector and multi-actor boundaries [12]. SH upgrading should be driven by collective inputs and feedback from stakeholders to ensure that user needs and expectations are met, and that values are delivered.

The upgrading of buildings, based on sustainability, is widely acknowledged as the axis of the building's stock reformulation [13], especially for social housing. For instance, retrofit interventions are critical to reducing energy consumption and CO_2 emissions [14,15]. In addition, conventional energy-efficiency approaches should be complemented by community or user-centred initiatives as opportunities for experimental, flexible, and customised SH upgrading [16].

SH upgrading processes can benefit from the adoption of the concept of Living Labs. This concept was created as a social innovation to improve participatory processes in real-life contexts. Through user-centric strategies collaboration is fostered among all stakeholders involved in decision making for viable solutions to existing problems [17]. Living Labs support value generation through the engagement of relevant stakeholders, which typically include end-users, researchers, as well as public and private partners [18]. External agents such as policymakers and investors are often also part of Living Labs to provide a wide collaborative learning perspective [11,19].

While traditional SH projects are usually top-down initiatives, Living Labs can foster bottom-up communication and collaboration between participants, especially users (i.e., residents), allowing social transformations [20]. Living Labs can solve problems in which user involvement is fundamental [18,19,21–23]. Existing research describes the application of Living Labs in the SH context (e.g., [24–27]). However, challenges exist to effectively implementing Living Labs focused on SH upgrading and improving value generation. There is a lack of clarity around which tools and strategies should be used to enable collaboration and clearly identify user requirements in the SH upgrade context. Additionally, to adequately address user needs, it is essential to consider the context to determine effective activities and tools for a successful Living Lab implementation.

2. Research Questions and Objectives

This paper explores the existing literature on the adoption of Living Labs in the housing context. It aims to respond to the following questions: (a) What is the usual process adopted in Living Labs?; (b) At which stage are different stakeholders involved in Living Labs?; (c) Which activities and tools have been reported in the literature to support housing Living Labs?; (d) What are the main challenges in adopting Living Labs that are applicable to the SH context?; and (e) Which recommendations can be proposed to the specific context of SH upgrading using Living Labs?

From our literature analysis, a generic Living Lab process model was proposed, and nine housing Living Lab cases were selected to characterise types of stakeholder participations across the four-phase scheme of a typical Living Lab. Based on these cases, activities and tools were also classified according to Living Lab stages and the type of participants involved, i.e., users, public and private partners, and researchers. Furthermore, the paper describes challenges highlighted by the existing literature that are applicable to SH upgrading using Living Labs, and recommendations to overcome these challenges are proposed. These can support the future adoption of Living Labs in the SH upgrading context.

This paper is structured as follows: In the following Section 3, a brief literature review on Living Labs provides an overview of the topic, including its origin, applications, and core constructs. Following this, Section 4 presents the research method applied in this study. Next, Section 5 presents the results. Finally, Section 6 closes the paper, discussing the findings, limitations, and future research.

This paper was developed as part of an ongoing research project aimed to support user-valued innovations in SH upgrading through transatlantic Living Labs in Brazil, England, Germany, and the Netherlands (uVITAL Project).

3. Living Labs

Although the term 'living laboratory' appears in earlier studies such as the "Aware Home" [28] and the "Classroom 2000" project [29], the first Living Lab initiative is usually attributed to MIT's professor William Mitchell's "PlaceLab": an apartment-scale research facility equipped with sensing devices in which volunteers were invited to live for a determined period of time to test emerging home technologies [21,30]. The idea behind temporarily moving people from their homes to live in a research facility (the living laboratory), was to reduce complexity and variability, so that it would be possible to accurately capture corresponding user behaviour [31].

The focus of early Living Labs was on innovative emerging technologies, especially ICT (Information and Communication Technologies) tools. Following this, Living Lab applications targeted innovation in different domains such as energy, media, mobility, and healthcare [32]. More recently, the Living Lab concept has also been explored at the urban level [33–35].

The Living Lab's horizontal organisational structure favours participants' knowledge and creative contributions to occur unrestrained by hierarchical boundaries [36]. Hence, Living Labs have been used to handle problems of high complexity involving conflicting interests [37,38].

Living Labs have an innovative character and, therefore, different Living Lab processes have been applied in a variety of ways. As a result, each reported Living Lab is unique: its design can be linear or non-linear, including the use of a variety of tools [17]. As an experimental and creative process, the application of Living Labs requires flexibility. Furthermore, as an intrinsic learning process [39], it involves some unpredictability in its process and outcomes [11].

There is no clear consensus on the definition for Living Labs in the literature [18,23,30,40]. Two main ways of understanding the concept of Living Labs can be found in the literature. These are: an environmental and a methodological approach. The environmental approach definition states that Living Labs are research facilities or physical places where innovation is developed [17,20,41–46]. The methodological approach describes specific activities of Living Labs to enable collaboration between the stakeholders involved [19,21,37,47–53]. With regard to the use of terminology, Van Geenhuizen [11] (p. 28) states "aside from innovation methodology, the term Living Labs often also refers to the (temporary) organizational structure in which the methodology is implemented".

The analysis of the literature highlighted that the concept of Living Labs is anchored to five core constructs: Research and Development, User-Centrism, Innovation, Collaboration, and Real-life context. These are described as follows.

(a) Research and Development: A Living Lab is seen as "a user-centric research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts" [21] (p. 4). A Living Lab is an interactive, scientific, and stakeholder-integrative research approach that needs real-life testbeds. As such, it constitutes a Research and Development method to collaboratively create and validate innovations in real-world environments. A Living Lab "blurs the distinctions between laboratory and field, inside and outside, as well as controlled and uncontrolled experiments" [54] (p. 128). It supports the creation and validation of products, services, and other solutions in real-world environments [55]. Hence, it triggers contributions to practice (by releasing innovations to market) and to theory (by developing scientific knowledge) [18].

(b) User-centrism: Living Labs rely on user participation to idealise, experiment, and evaluate a designed solution [56]. They focus on daily practices and problems in a real-life environment [19,21,56]. Users are co-creators in the design process and therefore have the opportunity to actively influence the solution development according to their own needs and expectations [23]. This process tends to increase the range of possible designed solutions, as well as improve the values generated through such developments [30], enabling innovation [11]. The project's success is primarily determined by end-users, emphasising the human dimension of a Living Lab [54].

(c) Innovation: Proposing innovative solutions is one of the main objectives of a Living Lab. Some authors describe Living Labs as an "innovation milieu" [18,57–59]. Innovations may relate to emerging and new technologies, services, products, and systems [17]. New products/solutions are co-created, prototyped, validated, and tested within collaborative and real environments [19,21,60]. Hence, Living Labs enable integrating technological, social, and governance processes [48,61]. This also contributes towards sustainable development by making better use of resources through participatory processes and decision-making [48,62].

(d) Collaboration: Facilitating stakeholders' engagement in innovation processes towards value creation is key in Living Labs [18,23]. Living Labs are means to promote collaborative learning [39]. Stakeholders should be involved from the earliest stages [63] to enable expertise sharing and knowledge transfer across disciplines [18]. It includes communication strategies to overcome potential conflicts and barriers among participants [38], and to facilitate early connections [64].

(e) Real-life context: The relevance of a real-life context is clearly emphasised by the literature, i.e., the existence of a physical place or environment in which people are brought together and experiments can take place. Real-life means being developed in a realistic context instead of collecting data in a laboratory [65]. This environment should not only represent the problem or challenge in question but also stimulate creativity and improvisation for testing and validating new solutions in practice [39]. Because Living Labs are developed in such a context, the results' validity tends to be increased [66]. This is the case, for example, of the Living Lab concept proposed by Ballon et al. [67] (p. 3): "An experimentation environment in which technology is given shape in real-life contexts and in which (end) users are considered co-producers". A further definition describes "Living Labs are physical regions or virtual realities in which stakeholders form public-private-people partnerships (4Ps) of firms, public agencies, universities, institutes, and users all collaborating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life environments" [68] (p. 20).

The five constructs are considered important for the successful implementation of the SH upgrading process using Living Labs. Research and development are imperative to deal with the challenges of upgrading the SH stock. SH users are not only the "recipients" of renovations for energy efficiency, but they also have social needs, place attachment, context knowledge, and individual needs and desires. In most cases, they also will inhabit dwellings during construction activities, which creates disruption and can be a source of conflict. Innovation is essential to solving SH problems, stimulating participation, and applying up-to-date technologies to support a collaborative environment, as well as to clarify conflicting understandings. Furthermore, both end-users and other stakeholders can benefit from a Living Lab through a collaborative learning process. However, for SH upgrading, there is a need to further define and evaluate appropriate processes and tools which can provide the best Living Lab results, and hence, better value delivery through SH upgrades for users.

4. Research Method

An integrative literature review [69] was adopted to answer the research questions of our study. Literature reviews are useful for providing an overview on a research problem and building conceptual models or mapping the development of a particular research field [69]. Integrative reviews address emerging topics seeking to synthesise the literature in a specific area, allowing the development of new theoretical frameworks and perspectives [70].

Our research method (Figure 1) follows four steps, as proposed by Snyder [69]: (1) designing the review, (2) conducting the review, (3) analysis, and (4) writing up.

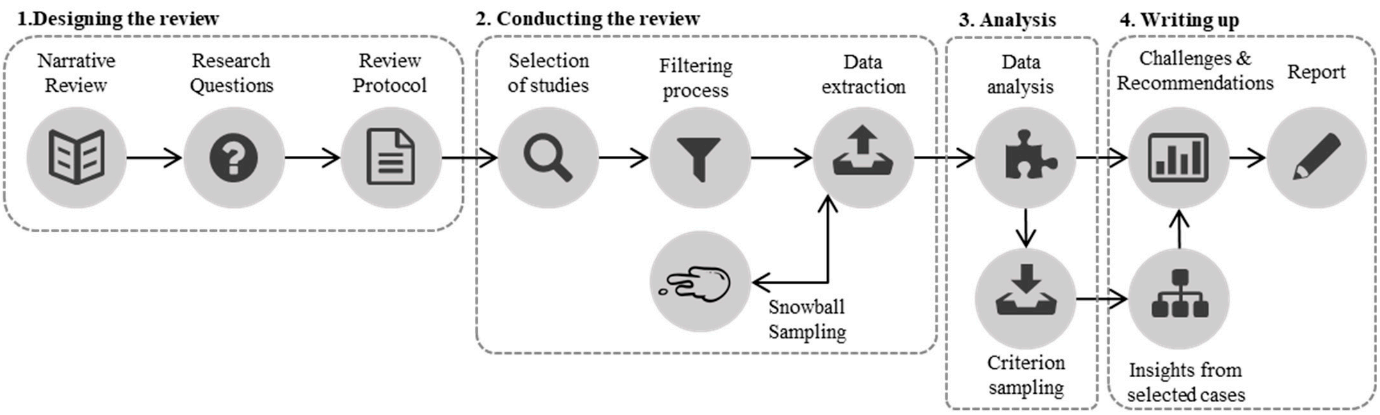

Figure 1. Research method conducted in this study.

In the first step "designing the review" (1), an initial narrative review is developed. This led to the refinement of the research questions, and subsequently, a review protocol was developed. The protocol determined strategies to access the literature (i.e., search strings, database selection) and quality assessment criteria for the selection of research papers and Living Lab cases to be further investigated. The protocol was refined throughout its implementation.

The "conducting the review" step (2) consisted in the identification of relevant Living Lab cases. Five databases (Science Direct, Springer Link, IEEE Explorer, MDPI, and Wiley) were selected according to the following criteria: possibility of using Boolean operators in all search formats; possibility to define specific search dates; possibility of specifying search terms in different fields of the document; type of publications (journal papers, conference papers, and reports); and supported export formats, such as BibTeX. The Scielo database was later included for its relevance in Latin America. The search string encompassed the terms ("Social Housing" OR "Low-Income Housing" OR "Affordable Housing" OR "Adequate* Housing") AND "Living Lab".

Figure 2 illustrates the number of studies found in the different stages of the review. In total, 604 documents were identified, and three filtering stages were applied. First, 101 duplicated documents were removed. Second, through an analysis of titles, abstracts, and keywords, 452 documents were rejected due to inconsistency with the search aim: documents not specifically focused on Living Labs; and documents not related to improvements on housing Living Labs. A total of 51 documents were accessed for full content reading (third filter). Exclusion criteria were applied in every step of the screening process, and 22 documents were excluded because they did not match the purpose of this review, with 29 documents remaining. A further 14 documents were included through snowball sampling [71]. Such "backward sampling" consisted of adding references from the sampled articles to the selection list [71].

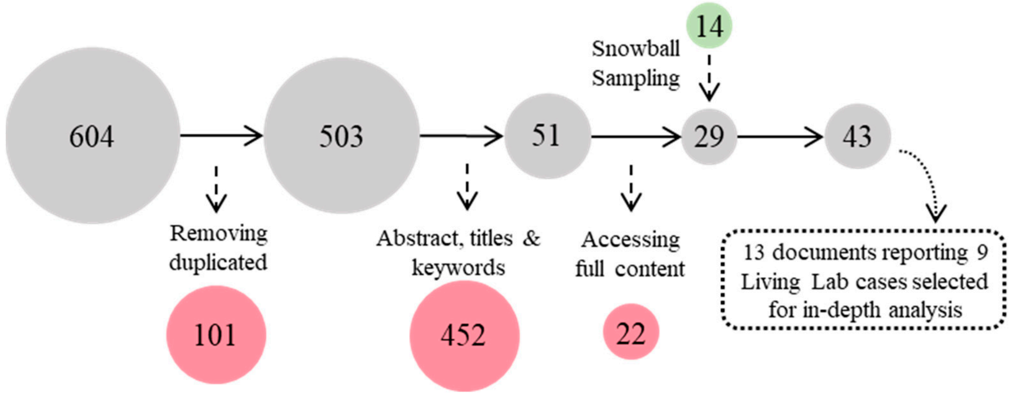

Figure 2. Identification and filtering of documents.

As research focusing specifically on SH upgrading using Living Labs was scarce, the reviewed Living Lab cases also included existing Living Labs within the housing literature in general, and social housing in particular, totalling 43 documents. Documents in English, Spanish, or Portuguese were included.

The 43-document sample includes 6 book chapters and 5 conference papers. The 32 papers in journals were produced by authors from 21 countries, but concentrated in Germany (17%), The Netherlands (13%), Sweden and Finland (9% each). The publications were from 17 journals. Although no time period was imposed in the screening criteria, the oldest publication found dated back to 2005, with a concentration of publications in 2017 (25%). Only one paper was recorded for 2020, as the search was performed in May 2020.

The "analysis" step (3) examines the gathered literature [69]. A "Criterion Sampling" technique was applied [72], aiming to select key information-rich cases when resources are limited [72]. The cases were selected not only in terms of their quality but also because of the amount of empirical information reported that allowed a better understanding of the Living Lab process, including the applied tools and participants engaged.

From the 43 documents selected for data extraction, 13 primary studies reporting 9 Living Lab housing cases were chosen for an in-depth analysis. For this we grouped different publications to gather sufficient information about each Living Lab case identified (e.g., Case D: [57] Baedeker et al., 2014, [25] Folta et al., 2017, [73] Lockton et al., 2013 and [26] Lockton et al., 2017). From the analysed cases, only 4 relate specifically to SH, however the other cases were also selected as they presented either scope, activities, or innovations that are relevant and have the potential to be applied in the SH upgrading context.

The final step (4) "Writing up" was organised in three parts. First, it included a description of the 9 selected Living Lab cases, the proposition of a four-stage Living Lab process model based on the literature and the development of a list of activities and tools adopted across the cases. In the second part, the 43-document sample was reviewed and the main challenges for implementing Living Labs that can be applicable within an SH context were extracted (Section 5.2). Finally, recommendations were proposed (Section 6).

5. Results

5.1. Living Labs: Insights from the Nine Selected Housing Cases

5.1.1. Living Lab's Purposes

The analysis of the literature shows that many publications provide partial reports of a Living Lab case or focus on one specific aspect of it. Generally, the publications lack detailed information about Living Lab activities. The investigated Living Lab cases had different purposes, as highlighted in Table 1. In all nine cases, stakeholders were residents of different types of housing, whereas other participants were varied. They included, for example, contractors, housing associations, and community leaders. Generally, in all cases researchers were the instigators of the Living Labs with specific problem-solving objectives. Sustainability goals drove eight cases, which focused on reducing energy consumption through combined efficiency and reduced carbon emissions. Only one of the nine studies addressed structural renovations and sanitation interventions, developed in a Brazilian SH Living Lab [74].

Table 1. Summary of the 9 housing Living Lab cases.

Living Labs Cases	Characteristics			
	Country	Context	Purpose	References
A: Multistorey SH case	Netherlands	Social Housing	Energy consumption reduction/Zero CO_2 emissions	[27]
B: ENERPAT	France	Old dwellings	Energy consumption reduction	[37]
C: Saint Katherine case	Egypt	Old dwellings	Energy consumption reduction	[75,76]
D: SusLabUK	UK	Social Housing	Energy consumption reduction	[25,26,57,73]
E: RenoseeC	Belgium	Social Housing	Energy consumption reduction	[24]
F: Trondheim Living Lab *	Norway	Living Lab research facility	Zero CO_2 emissions	[44]
G: SusLabNRW	Germany	Living Lab research facility/Housing (in general)	Energy consumption reduction	[25,57,58]
H: Habitat Living Lab	Brazil	Social Housing	Structural renovation, Water, sanitation, and hygiene interventions	[74]
I: Livewell Yarra	Australia	Housing (in general)	Zero CO_2 emissions	[77]

* This case is not necessarily referring to upgrading but it explores potential solutions that can be applied to SH upgrades.

SH upgrading cases generally pursue energy efficiency by renovating heating systems or refurbishing the building envelope. As part of a larger Living Lab initiative (i.e., Baedeker et al. [57]), a case in the UK involved SH users (tenants) [25]. This project was part of an energy reduction programme (see [26]). The aim was to understand users' routines, motivations, and interactions with technology to provide insights for further interventions.

The case reported by Boess [27] was aimed at carbon neutrality. The Living Lab was used to involve residents in their everyday "after renovation" practices. It included a real scale demo-flat where users participated in experimenting with a new cooker and ventilation system.

Heuts and Versele [24] demonstrated a Living Lab that involved low-income families to develop affordable renovation plans for twenty houses in Belgium. The case aimed at developing a business model for private housing renovations which included cooperation with supply chain participants. The goal was to understand the process's scalability and replicability, focusing on a vulnerable population.

Other studies—not explicitly targeting SH—investigated general housing renovations to reduce energy costs and increase thermal comfort. Claude et al. [37] reported on a French Living Lab to improve old, unoccupied dwellings, but users were not involved in this case. Furthermore, a Living Lab case in Egypt engaged users in assembling and using a Trombe wall system for cooling and heating purposes [75,76].

Other housing Living Lab cases were specifically developed within university premises. These were conducted in research facilities or as part of urban Living Labs. Generally, users were invited to move into a research facility (e.g., a laboratory) for a determined period or to participate by experimenting and evaluating prototypes. One example of this case is a Norwegian Living Lab [44], which was a single-family research unit where different families were invited to live for 25 days in a zero-carbon emission building. Observations of behaviour were analysed, and the participant families evaluated the building and its facilities. A German Living Lab case [58] included both a research facility and real householders to develop heating solutions.

Housing Living Labs were also developed as part of urban experiments, for example, an Australian urban Living Lab engaged home users in renovations for low-carbon living [77]. Users from the target area participated in several decarb group meetings and workshops as a way to empower them for collective sustainable behaviour. The authors reported achievements ranging from small changes (e.g., reducing car usage and switching electricity suppliers) to house upgrades (e.g., replacing home insulation and draft-proofing windows and doors).

5.1.2. Living Lab Process

This section aims to discuss the two first research questions: (a) What is the process generally adopted in Living Labs? and (b) At which stages different stakeholders are involved in Living Labs?

Despite the importance of the process through which a Living Lab is implemented in practice, detailed process models and descriptions are rarely observed in the literature. Only Living Lab case D and case G (see Table 1) explicitly described a linear, three-phase model: Insight research, Prototyping, and Field Testing [58]. "Insight research" involved understanding the building characteristics, including energy consumption and social practices. "Prototyping" referred to co-creating and developing solutions with participants, whilst the "Field-Testing" phase was dedicated to evaluating and redesigning, if necessary.

Furthermore, from the initial narrative literature review, two studies highlighted non-linear phases and iterative (three- or four-step) loops in the Living Lab process. Bergvall-Kåreborn et al. [18] proposed a five-stage model, in which "Generate Needs", "Design", and "Evaluate" follow the "Planning" phase and iterate until "Commercialisation'. Similarly, Tang and Hämäläinen [22] synthesised a Living Lab process into an iterative four-step model ("Requirements", "Co-design", "Prototyping", "Test and Tracking") plus an "exit phase" (Commercialisation). In both structures, an initial phase identifies the real-life issues to be solved (preceded by a separate planning stage) and the final stage is the "exit to commercialisation" of the marketable product. Moreover, Tang and Hämäläinen [22] highlight the role played by users and other stakeholders not only in co-designing the solution and co-developing innovations, but also in their assessment and evaluation in real-life contexts.

Despite the similarities of existing process models, the variety of information from the analysed publications highlights that there is no standard and widely acknowledged Living Lab process. Aiming to synthesise common characteristics of the models described above, Figure 3 presents a Living Lab process model, proposed on the basis of the literature analysis. The phases include: (1) Definition, (2) Ideation, (3) Co-creation, and (4) Evaluation.

"Definition" involves understanding the problem. This may include specifying the upgrading purpose, e.g., decreasing energy consumption as in Claude et al. [37]. "Ideation" refers to the collective definition of the idea or focus on the Living Lab, while "Co-creation" is the solution development itself. Finally, "Evaluation" encompasses testing the solution, feedback, and reporting.

As phases can be iterative, the circular shape and arrows in Figure 3 represent the Living Lab's learning character, flexibility, and cycles. During the analysis of the selected Living Lab cases, one can notice that different participants join in different phases across the Living Labs process. Therefore, Figure 3 also highlights participants' involvement in the Living Lab cases according to their role: partners (i.e., public and private stakeholders), which are represented by blue circles, and users (represented by yellow circles). In this representation, the size of the circles is proportional to the participants' involvement level in the different Living Lab phases across the nine cases. Researchers were not highlighted in the figure, as they participate in all phases of the analysed cases.

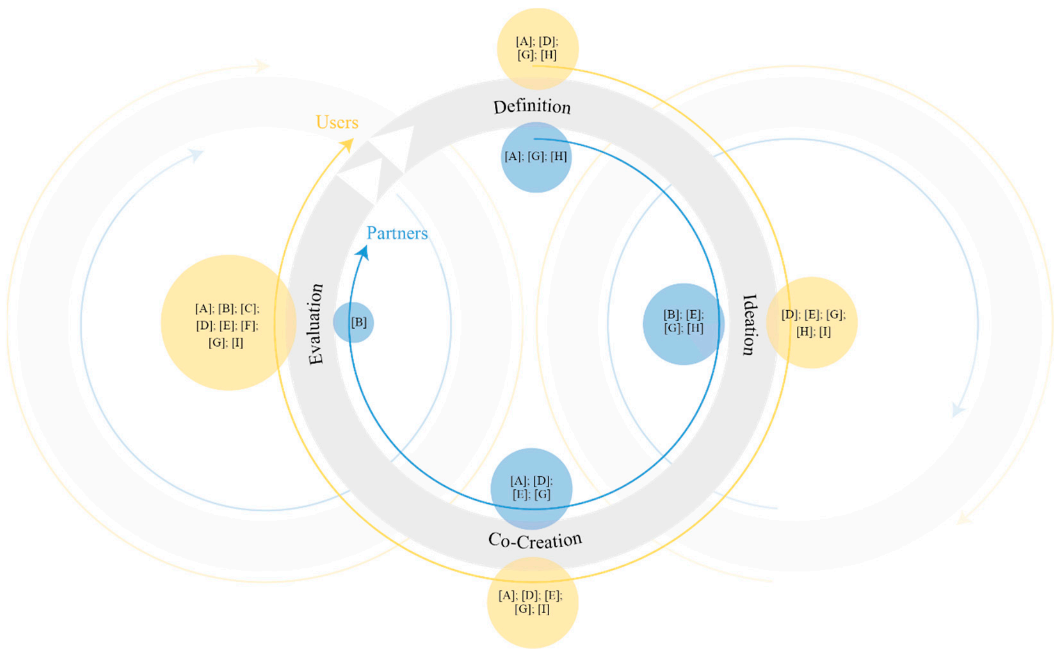

Figure 3. Living Lab process model based on the literature highlighting stakeholders' participation according to Living Lab cases (see Table 1). Note: Case A: [27]; Case B: [37]; Case C: [75,76]; Case D: [25,26,57,73]; Case E: [24]; Case F: [44]; Case G: [25,57,58]; Case H: [74]; Case I: [77].

As illustrated in Figure 3, most of identified cases do not include the ideal user-centred approach as usually highlighted in Living Lab definitions. Conversely, Living Lab partners generally participate during all stages of Living Labs. As highlighted in Figure 3, users were predominantly involved in the evaluation phase, to test and provide feedback on a given proposal. This phase also hosted most activities and tools (see Table 2). Since one of the constructs of Living Labs is user centrism, enabling effective strategies to actively involve all participants during the entire Living Lab process is paramount.

Table 2. Living Labs main activities, according to the stages and stakeholders involved.

Activities	Engagement *	Definition	Ideation	Co-Creation	Evaluation
Unstructured interviews (in local meetings)	C [75]				
POE—Post Occupancy Evaluation (thermal performance survey)					C [75]
Interviews			G [58] H [74]		F [44] DG [57] I [77]
Semi-structured qualitative interviews		D [58]			F [44]
Dialogue workshops			G [58]		
Reflexive Narratives (personal visits)		A [27]			
Consulting meeting		H [74]			

Table 2. *Cont.*

Activities	Engagement *	Definition	Ideation	Co-Creation	Evaluation
Workshops		G [58] 🗣 🤝 🔍	B [37] 🤝 🔍 G [58] 🤝 🔍 I [77] 🗣 🤝 🔍	D [25,26,57] 🗣 🤝 🔍 G [25,57] 🗣 🤝 🔍 I [77] 🗣 🤝 🔍	
Self-critical assessment					C [75] 🔍
Networking meetings			G [25] 🤝 🔍		
Information meetings	E [24] 🗣 🔍				
Hackathon (Home Energy Hackday)				D [25,26,73] 🗣 🤝 🔍	
Participant observation		G [57,58] 🗣 🔍			C [75] 🗣 🔍 F [44] 🗣 🔍 G [57] 🗣 🔍
Walkthroughs					C [75] 🗣 🔍
Simulations			C [75] 🔍		
Group dynamic			H [74] 🗣 🤝 🔍		
Evening session (complaints)		A [27] 🗣 🤝 🔍			
Informal Chats				A [27] 🗣 🤝 🔍	
Collaborative assembly				C [75] 🗣 🔍	
Field visits		D [25] 🗣 🔍 G [25,58] 🗣 🔍			C [75] 🗣 🔍
Onsite monitoring		G [58] 🗣 🔍			B [37] 🤝 🔍 C [75] 🗣 🔍 E [24] 🗣 🔍
Annotation and pictures exercise		D [26] 🗣			
Free housing scan	E [24] 🗣 🔍				
Self-filming					F [44] 🗣

Note: Types of stakeholders involved according to the 9 cases selected: 🗣: users; 🤝: partners; 🔍: researchers.
* "Engagement" is not a Living Lab phase but consists of activities that happen during different stages.

5.1.3. Living Lab's Activities and Tools

This section aims to respond to the following question: (c) Which activities and tools have been reported in the literature to support housing Living Labs?

A Living Lab requires participant engagement. Living Labs usually involve several actors, and the duration of their involvement varies. During this process, different tools can be used to support Living Lab activities [22].

Within the field of Information and Communication Technologies (ICT), for instance, Tang and Hamalainen [78] proposed the use of traditional and ICT-adapted methods for both real-life and laboratory applications. Laboratory methods are more controllable and include either remote or face-to-face activities (e.g., interviews, focus groups), whereas real-life activities are carried out in a less controllable environment, such as Living Lab facilities (e.g., MIT PlaceLab), market research, and field trials.

The key Living Lab activities identified in the literature are summarised in Table 2, according to the stage in which they occur, and the stakeholders (i.e., users, public and private partners, and researchers) involved in each activity. The table also indicates the Living Lab cases from the literature in which the activities are referred to.

Table 2 highlights the different activities used across the Living Lab stages. Such activities have varied purposes and include different participants. The activities used to recruit and engage participants throughout the Living Lab process consisted of interviews, meetings and a housing scan in one of the cases [24]. Heuts and Versele [24] reported that researchers visited the houses to perform basic screenings (e.g., CO_2 levels, presence of moisture problems, and insulation conditions) and to collect socioeconomic data. This led to increased trust in the Living Lab, allowing user's needs to be targeted. The main purpose of engagement activities is to motivate participants (especially users) with the Living Lab process, as well as to identify needs and requirements.

Interviews are used to support early Living Lab stages, becoming once again relevant to evaluate Living Lab results, including mostly users and researchers. It is interesting to note that during the ideation stage of the living labs reported in the literature, users were rarely involved, which highlights a potential gap in terms of current Living Lab implementations. Table 2 also highlights the fact that partners do not often participate in the evaluation stages (e.g., monitoring activities), where users are clearly involved.

The main tools adopted in Living Labs are presented in Table 3. The table has been organised according to the Living Lab stages and it identifies the participants that were involved in applying those tools. Accordingly, Tables 2 and 3 present interdependent contents.

Table 3. Living Labs main tools, according to the stages and stakeholders involved.

Tools	Engagement *	Definition	Ideation	Co-Creation	Evaluation
POE interview protocol					C [75]
Semi-structured interview protocol		D [58]			F [44]
Invitation letter	A [27] G [25]				
Postings and announcements	D [25,26] G [25]				
Gift vouchers	D [25,26]				
Real scale mock-up					A [27]
Scenario analysis				E [24]	
A2 boards (visualisation of the renovation)				A [27]	
Samples of physical components				A [27]	
Prototypes				D [26] G [57]	
Energy displays		D [25,73]			
Monitoring toolkit (tablet for self-reporting)		G [25]			G [25] F [44]
Diary records					F [44] A [27]
Camera (self-filming)					F [44]

Table 3. *Cont.*

Tools	Engagement *	Definition	Ideation	Co-Creation	Evaluation
Tags		D [26]			
Sensor Technology		DG [57]			

Note: Types of stakeholders involved: : users; : partners; : researchers. * "Engagement" does not consist of a Living Lab phase but relates to activities that happen across the different Living Lab stages.

5.2. Challenges in Social Housing Upgrade Living Labs

This section aims to answer to the following research question: (d) What are the main challenges in adopting Living Labs that are applicable to the SH context?

The scale of reported Living Labs stretches from very specific improvements in building systems to innovative urban interventions. Even though not all the cases analysed in this paper relate specifically to SH, either their scope, activities, or innovations could be applied to the SH context.

Although the review shows predominantly positive aspects of Living Labs that can benefit SH upgrading processes, existing research also indicates that special efforts are needed to implement Living Labs, which can be understood as challenges in this context. The main difficulties in implementing Living Labs identified in the literature are presented below, describing five main challenges for the adoption of Living Labs in SH upgrading.

- Companies are sceptical about the benefits arising from user integration: The intrinsic user involvement in Living Labs can be compromised by difficulties in engaging with end-users. This can be even more challenging for SH context applications. The level of stakeholder engagement impacts on outcomes, specially to ideate and co-create solutions [45]. While collaboration with research and public institutions are generally developed more easily, private company representatives often have difficulties to understand the benefits of user-centred approaches before participating in Living Labs [59]. Additionally, the Living Lab open innovation focus can hinder companies from joining due to intellectual property (patent) related issues [20].
- Vulnerability of social housing residents and user involvement: A specific characteristic of SH Living Labs relates to its focus on people that are vulnerable or to homelessness. This affects the early stage of engaging participants as reported by Heuts and Versele [24]. The authors emphasise the need for social cohesion, recognising people's potential to collaborate through personal contact and direct communication. Therefore, working with vulnerable target groups, such as social housing users, requires special efforts and time [24] which can affect the overall duration of a Living Lab.
- Cultural differences and perspectives between the Living Lab participants: Living Labs benefit from involving participants that have varied perspectives, based on personal values and worldviews [18]. Conversely, that also means that conflicting views and different perspectives between participants may increase the Living Lab complexity [37] and potentially hinder cooperation and co-creation. These factors can further influence the communication between participants, impacting the Living Lab progress and/or quality of outputs to be achieved.
- Difficulties involved in managing Living Labs: The Living Lab implementation requires considerable time, efforts, and financial resources. This creates extra management activities and potentially introduces difficulties in the process. The lack of public policies for financial support is a common constraint observed across Living Labs [74]. Furthermore, complexity arises from the need to manage a number of participants in the process [74], which further creates difficulties in ensuring that all those collaborating in the Living Lab are adequately supported [51]. Finally, a poor integration with the network of Living Labs participants to foster discussion and external collaboration can be a burden [74].

- Validity and generalisation of Living Lab results: Living Lab results are generally restricted to a specific context within a certain time period and to solve well-specified needs [45]. Therefore, results from different initiatives can hardly be generalised to broader contexts [79] and depend on continuous monitoring and control processes [77]. In this context, results from one Living Lab can hardly be generalised and applied to different contexts [74].

6. Discussions

This section aims to respond to the last research question: (e) Which recommendations can be proposed to the specific context of SH upgrading using Living Labs? Considering the challenges previously discussed, a series of recommendations for the development of Living Labs in the context of upgrading social housing is proposed.

Although most of these recommendations can be generally applicable for any Living Lab, they become especially relevant to the specific SH upgrading context considering the challenges discussed above.

The recommendations are as follows:

(a) Focus on people and their engagement: Personal contact and the importance of listening to complaints are essential to gaining trust, as mentioned by Liedtke et al. [58]. Efforts to engage participants should focus on local issues in their environment (context), inspiring people to discuss and experiment with innovative solutions through activities such as using models, prototypes, and being involved in design competitions [1]. Users should be involved in every stage of the decision-making process in an interactive way, increasing their acceptance on the proposed solution [76]. Suggestions of engagement activities are presented in Table 2.

(b) Increase participant's motivation and satisfaction: All Living Lab phases should be developed to motivate participants [34]. They should feel satisfied not only with the results but with the process [11]. End-users should effectively contribute to decision-making and co-creation.

(c) Plan the duration of Living Labs: Working with vulnerable groups and achieving effective participation in the decision-making process can increase the duration of Living Lab processes but will likely increase the acceptance of the proposed solutions [76]. The planning of Living Labs needs to take this actively into account.

(d) Enable user empowerment and ownership: Living Labs cases reported by Sharp and Salter [77] showed that participants not only felt empowered to make changes in their lifestyle but also to conduct additional experiments in their homes and communities. Empowerment and collaborative partnerships are essential as they have the potential to improve social, economic, environmental, and cultural outcomes [61].

(e) Seek for wide stakeholder cooperation: It is important to involve a diversity of perspectives in a Living Lab. While complexity may increase due to the heterogeneity and different backgrounds of participants [74], the Living Lab approach can bridge the gap between researching and delivering innovative solutions in real and complex environments [37]. This includes end user inputs but also considers the value chain partners as centrepieces of the process [9,18,19,30]. Suggestion of tools reported by previous studies to support stakeholders' cooperation are indicated in Table 3.

(f) Value learning: The existence of conflicting views can challenge the success of any upgrade project. Living Labs provide opportunities to unexpected discoveries and learning that comes from the users since it prioritises user-centred experimentation [80]. It also enables stakeholders to achieve some common ground in relation to what is feasible and possible across the upgrade process [38], which would be of benefit both for the quality of the end product, and also in supporting user satisfaction after the upgrade/retrofit is finished.

(g) Consider the need for mediation: Mediation efforts should be carried out to overcome differences among participants with conflicting needs and values. Hence, the use of a facilitator is indicated to increase coordination and qualify the dialogue in support of the project's progress [37]. This can be facilitated through the involvement of boundary spanners (Boundary spanners are "people who proactively scan the organisational environment, employ activities to cross organisational or institutional boundaries, generate and mediate the information flow and coordinate between their "home" organisation or organisational unit and its environment, and connect processes and actors across these boundaries." [81] (p. 3)). These are trustable actors that can cross the boundaries between different communities [53].

(h) Promote the benefits to private partners: Companies can benefit from applying user-centred approaches, as they reduce the risk of design solutions or other innovations being rejected by users [59]. However, the definition of strategies to encourage companies to join SH upgrade Living Labs may be challenging and needs further research.

(i) Focus on innovative solutions: Living Labs should enable community-driven innovation [22,60], by improving local developments [61]. Current practices and their influence on society should be analysed during planning and during the development of Living Labs [48].

7. Conclusions

Living Labs originated in the context of Information and Communication Technologies and have been applied in diverse contexts—including housing and urban innovations—to emphasise participant involvement to support collaborative learning, decision-making, and innovative co-creation.

Living Labs initiatives became increasing popular in the past decade, but the scientific community seems to have not reached consensus on concepts or their implementation. Additionally, some important issues concerning how tools and techniques for capturing user needs and engaging with stakeholders have been overlooked. This lack of a consolidated body of knowledge and practice impairs a systematic and structured approach for designing new living labs, which basically begin from scratch each time.

To help to shift towards a more structured adoption of Living Labs, we scrutinised case studies found in the literature to: (1) relate tools and activities to the experiment stage and to stakeholders involved; (2) identify the potential challenges for adopting living labs in social housing upgrades; and (3) explore the characteristics of housing Living Labs and put them in the specific perspective of social housing upgrading.

As in any systematic string-based literature search, publications dealing with living labs-like approaches might have been excluded from our search for not using the exact term. Additionally, living labs are usually long-term projects, published in a series of partial achievements reports, which would be classified as "grey literature" and excluded from our search. Still, meaningful insights could be extracted.

Four iterative Living Lab phases were identified, as well as stakeholders typically involved, and supporting tools and activities used. Findings show that end-users are occasionally involved in co-creation and, most often, in the evaluation stage. Public and private partners mostly join the initial (definition and ideation) phases, with little evidence of interaction continuity in the subsequent stages.

Finally, we proposed recommendations to overcome typical challenges of using such an approach when specifically focusing on social housing upgrading, be it driven by sustainability objectives or tailored to handle health, connectivity, accessibility, and other relevant concerns.

By following certain protocols and focusing on social innovation, Living Labs can contribute to complex problem-solving such as social housing upgrading. Many aspects of housing Living Labs found in this review could be potentially applied within the SH context. However, further research is needed to assertively bridge this knowledge gap. In this sense, the next steps of the uVital project include implementing an SH upgrading Living Lab case, to evaluate tools and validate the recommendations herein presented.

Author Contributions: Conceptualization, M.E.B., J.S.-J., A.D.G. and V.G.; Methodology, M.E.B. and J.S.-J.; Investigation, M.E.B. and J.S.-J.; Writing—Original Draft, M.E.B. and J.S.-J.; Supervision, A.D.G. and P.T.; Writing—Review and Editing, M.E.B., J.S.-J., A.D.G., P.T., V.G. and D.C.C.K.K.; Funding Acquisition, A.D.G., P.T., V.G. and D.C.C.K.K.; Project Administration, D.C.C.K.K. All authors have read and agreed to the published version of the manuscript.

Funding: This paper reports on partial results from the uVITAL project, funded by the Trans-Atlantic Platform for Social Sciences and Humanities (ES/T015160/1) and Economic and Social Research Council (ESRC): #ES/T015160/1. The authors thank the Fundação de Amparo à Pesquisa do Estado de São Paulo—FAPESP [Process #2019/02240-5]; Coordination for the Improvement of Higher Education Personnel—CAPES for their generous funding support; and the National Council for Scientific and Technological Development—CNPq for the individual productivity grants #302080/2017-1, #311146/2020-1, and #306048/2018-3.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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