RE-DWELL
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A transdisciplinary perspective on "Design, Planning and Building"

Deliverable 4.1

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RE-DWELL

Deliverable 4.1. A transdisciplinary perspective on “Design, Planning and Building”

Version 1

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Table of contents

Executive summary

This report presents the work undertaken in Task 4.1 "A transdisciplinary perspective on Design, Planning, and Building" which together with Task 4.2 “A transdisciplinary perspective on Community Participation" (Deliverable 4.2) and Task 4.3 “A transdisciplinary perspective on Policy and Financing" (Deliverable 4.3) constitute a core component of RE-DWELL’s Work Package 4 “Transdisciplinary affordable and sustainable housing research framework”. The primary goal of these three tasks is to equip Early-Stage Researchers (ESRs) with the methodologies and tools necessary to conduct their research on affordable and sustainable housing from a transdisciplinary perspective.

The work contained in this document has been developed in parallel with the work reported in Deliverables 4.2 and 4.3. To carry out these three lines of inquiry along each of RE-DWELL’s three intertwined research areas – “Design, Planning, Building”, “Community Participation” and “Policy and Financing”–, 14 ESRs have been assigned to one of the three research areas most relevant to their research projects.

The process of the three lines of work has been as follows:

- Identifying key issues derived from the work conducted in the ESR research projects
- Deriving societal challenges related to the issues identified the research projects
- Interlinking challenges across the three research areas

Key themes identified by five research projects focusing on the “Design, Planning, Building” area include the global shortage of sustainable homes and the environmental impacts of construction; the pressing need for sustainable materials and innovative construction techniques to enhance energy efficiency and reduce costs; the importance of ensuring spatial efficiency and inclusive design to cater to diverse demographic needs; the potential of mass customization and participatory methodologies to empower communities and residents; the necessity of simplifying the regulatory framework to facilitate the development of sustainable social housing; the prioritization of health and long-term financial sustainability to ensure the viability and maintenance of housing; the need to address social housing rehabilitation and the promotion of circular, social, and affordable housing.

A transdisciplinary approach to affordable and sustainable housing requires the involvement of non-academic stakeholders who can identify and effectively address housing problems through their knowledge and experience. With this purpose, the topics identified through the research projects are conveyed as challenges in accessible language to facilitate dialogue with a broad audience. Key challenges span environmental, social, economic, and institutional dimensions, operating at various scales from individual buildings to regions, and involving diverse actors, methods and tools. These challenges include the integration of design for disassembly principles with industrialised construction practices to reduce the embodied carbon impacts of housing over the building lifecycle; the lack of early integration of resident stakeholders in housing retrofit to yield benefits such as cost savings, reduced performance gaps, and increased social value; the underutilisation of Life Cycle Costing (LCC) for households which often leads to oversights in investing in tangible features that impact residents’ health and financial wellbeing in the long term; the complexity of the regulatory framework governing the sustainability of social housing and the need to meet the diverse range of needs in multi-family housing within an affordable and sustainable framework through mass customisation strategies.

The report concludes by identifying several issues that span across the three RE-DWELL research areas, which are pertinent for future research and real-world activities aimed at providing affordable and sustainable housing:

- **Early stakeholder engagement**. Ensuring that solutions effectively meet the actual needs and preferences of residents by involving them in the design and construction process.
- **Interdisciplinary collaboration**. Breaking down silos within the construction sector to enhance processes and minimize environmental impacts through collaboration across different domains and disciplines.
- **Policy and financial alignment**. Addressing political and financial obstacles that hinder the adoption of sustainable practices in housing development.
- **Community and policy support**. Engaging communities to stimulate demand for sustainable housing solutions and garnering support from policies that promote such initiatives
- **Regulatory navigation**. Developing shared vocabularies and frameworks to navigate complex regulatory environments.

Addressing these themes holistically and through transdisciplinary collaboration can greatly enhance the effectiveness, sustainability, and social inclusivity of housing projects, ensuring the implementation of user-centred solutions, optimized processes, sustainable practices, and clear regulatory frameworks that facilitate compliance and collaboration.

1. Introduction

The work contained in this report is part of the construction of a research framework for affordable and sustainable housing carried out with the objective of equipping Early-stage Researchers (ESRs) with the methods and tools necessary to conduct their research within a transdisciplinary perspective.

Through various activities carried out over the three years of the network—which include training and research in diverse environments—researchers have had the opportunity to integrate theoretical insights from various disciplines with their research objectives. This fostered the acquisition of skills to implement a transdisciplinary approach to address the challenges currently facing the provision of affordable and sustainable housing. The ultimate objective is to establish a shared language to link individual research with the expertise provided by scholars and professionals from the ten universities and twelve non-academic organizations involved in the RE-DWELL network, and to develop and apply methods that facilitate dialogue between experts and non-experts in real-world cases aimed at addressing contemporary housing issues.

The main purpose of Work Package 4, “Transdisciplinary Affordable and Sustainable Housing Research Framework,” is to facilitate the creation of interlinks among the ESRs' projects across the three intertwined research areas that make the RE-DWELL comprehensive approach to housing –“Design, Planning, and Building” (Deliverable 4.1), Community Participation" (Deliverable 4.2) and "Policy and Financing” (Deliverable 4.3)– , spanning across academic and non-academic realms (Figure 1).

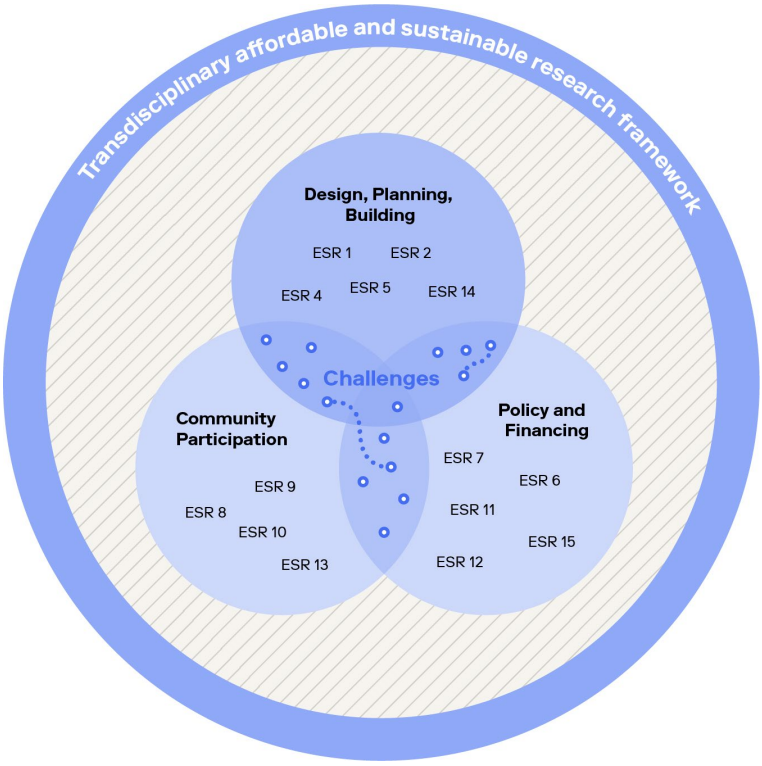

Figure 1. RE-DWELL's transdisciplinary research framework highlighting challenges arising from the interaction among three research areas, with a focus on “Design, Planning, Building”

As a result of the activities carried out in the network, a rich research environment has been created through the interweaving of the ESRs' projects and their interactions with academic supervisors and non-academic partner organizations. Following a bottom-up approach, the construction of this environment started with the ESRs' research projects (Figure 2). At the outset, the fifteen projects addressed multiple issues related to the provision of affordable and sustainable housing which potentially spans various domains and involves diverse professional fields (e.g. "Tensions between affordability and sustainability and the implications for vulnerable groups", "Lifecycle cost analysis and socioeconomic impact of existing social housing construction methods").

Throughout the activities conducted within the network, various components of the transdisciplinary research framework were introduced and interconnected:

- A vocabulary (Deliverable 4.4) consisting of definitions of key terms stemming from the individual research, and case study library (Deliverable 4.5) of relevant examples related to the RE-DWELL multidisciplinary approach to affordable and sustainable housing started to be collaboratively created at the start of the network activities and continued until their end.
- The research conducted by ESR projects related to each of the three intertwined research areas and complemented with their secondments, converging into a set of societal challenges (Deliverables 4.1, 4.2 and 4.3).
- Research on transdisciplinary methodologies within Deliverable 4.6 "Transdisciplinary research framework" provided a tripartite structure of systems, target and transformational knowledge to be used as shared language between stakeholders involved in real-world housing initiatives.
- The application of the framework components to specific cases, with local stakeholders, participatory techniques, including serious games and focus groups (Deliverable 4.7).

During the development of the collaborative research, throughout courses, workshops and field studies, these components became interlinked in multiple ways.

- Vocabulary terms and case studies relationships are linked on the website.
- Challenges are the result of both the scientific research undertaken within ESRs projects and the insights provided from non-academic stakeholders, including partner organisations and third-parties contacted by researchers in the course of their project.
- Participatory activities implemented in real-case scenarios applied the knowledge gained during the development of a shared language.

Ultimately, the goal of this transdisciplinary research work carried out by the network is to have a societal impact on stakeholders involved in the provision of affordable and sustainable housing. With this purpose, Deliverable 5.16-17 "Exploitation Plan" will develop strategies and communication campaigns specifically directed at exploiting the research findings in non-academic sectors (administration, industry, community).

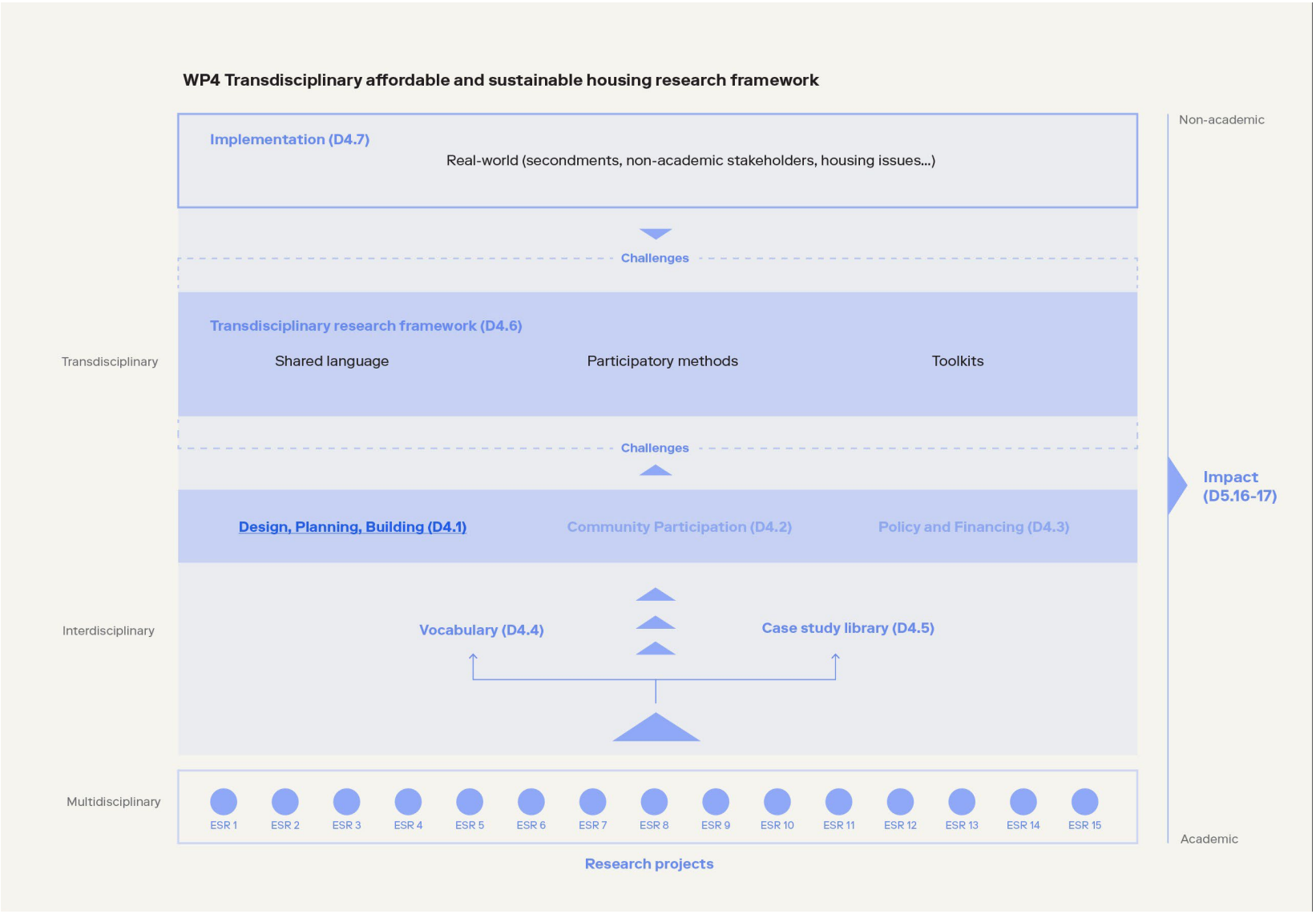

Figure 2. Components of the transdisciplinary research framework

Interrelated research areas

“A transdisciplinary perspective on Design, Planning, Building” is one of the lines of work carried out within WP4 aimed at identifying research pathways cutting across three research areas – the other two being "Community Participation" (Deliverable 4.2) and "Policy and Financing" (Deliverable 4.3) – which become intertwined in the transdisciplinary research on affordable and sustainable housing conducted by early-stage researchers in the RE-DWELL innovative training network.

The research area “Design, Planning, Building” primarily addresses the work of professionals such as architects, engineers, urban planners, planning administrations, building components manufacturers, and construction companies in the provision of affordable and sustainable housing. These professionals collectively hold responsibility for facilitating housing development areas that are well-connected to transport and energy networks, designing and building dwellings that maximize utility and comfort while minimizing costs and environmental impact, and using technologies that reduce construction time and natural resource usage. Their work is also connected to two other research areas, emphasizing the urgency of involving residents in planning and design processes (“Community Participation”), promoting changes in existing planning regulations, and contributing to the creation of housing projects that are environmentally sustainable, socially responsible, and ethically managed (“Policy and Financing”.

The work contained in this document has been developed in parallel with the work reported in Deliverables 4.2, "A Transdisciplinary Perspective on Community Participation" and 4.3 “ A Transdisciplinary Perspective on Policy and Financing”. The work carried out along these three lines focuses on one of the research areas while aiming to identify issues in the other two, with which they can be interrelated, in order to gain a comprehensive understanding of the challenges involved in providing housing that is both affordable and sustainable.

The process followed in the three reports has been as follows:

1. Identifying key issues derived from the work conducted in the ESR research projects
2. Deriving societal challenges related to the issues identified in the research projects
3. Interlinking challenges across the three research areas

To carry out the three lines of work, the 14 ESRs were assigned to the areas which were most relevant to their research projects, as reflected in Table 1.

Table 1. ESRs and research areas

Research area	ESRs
Design, Planning, Building	**Annette Davis (ESR1)** **Saskia Furman (ESR2)** **Aya Elghandour (ESR4)** **Mahmoud Alsaeed (ESR5)** **Carolina Martín (ESR14)**
Community Participation	Andreas Panagidis (ESR8) Effrosyni Roussou (ESR9) Zoe Tzika (ESR10) Androniki Pappa (ESR13)
Policy and Financing	Marko Horvat (ESR6) Anna Martin (ESR7) Tijn Croon (ESR11) Alex Fernández (ESR12) Leonardo Ricaurte (ESR15)

2. Structure of the report

The working process transitioned from individual research projects to societal challenges spanning across the three research areas as reflected in the structure of this report (Figure 3).

Section 3 introduces some of the key research issues encompassed in the subject area of "Design, Planning, and Building," which are derived from the work conducted by the ESRs. It is divided into three subsections: a summary of the research projects, including research questions and expected outcomes, and a literature review on key issues related to the research topic.

Based on the knowledge gained throughout their research projects, as well as in the activities within RE-DWELL, researchers have identified a series of societal challenges, presented in Section 4. The description of the challenges includes the actors, methods, and tools involved, as well as the related entries in the shared vocabulary and case study library.

In Section 5, each challenge identified within the area of "Design, Planning, and Building" is related to the challenges proposed by researchers working on the other two research areas, "Community Participation" and "Policy and Financing."

Finally, Section 6 contains a reflection on the work done and suggests directions for future research.

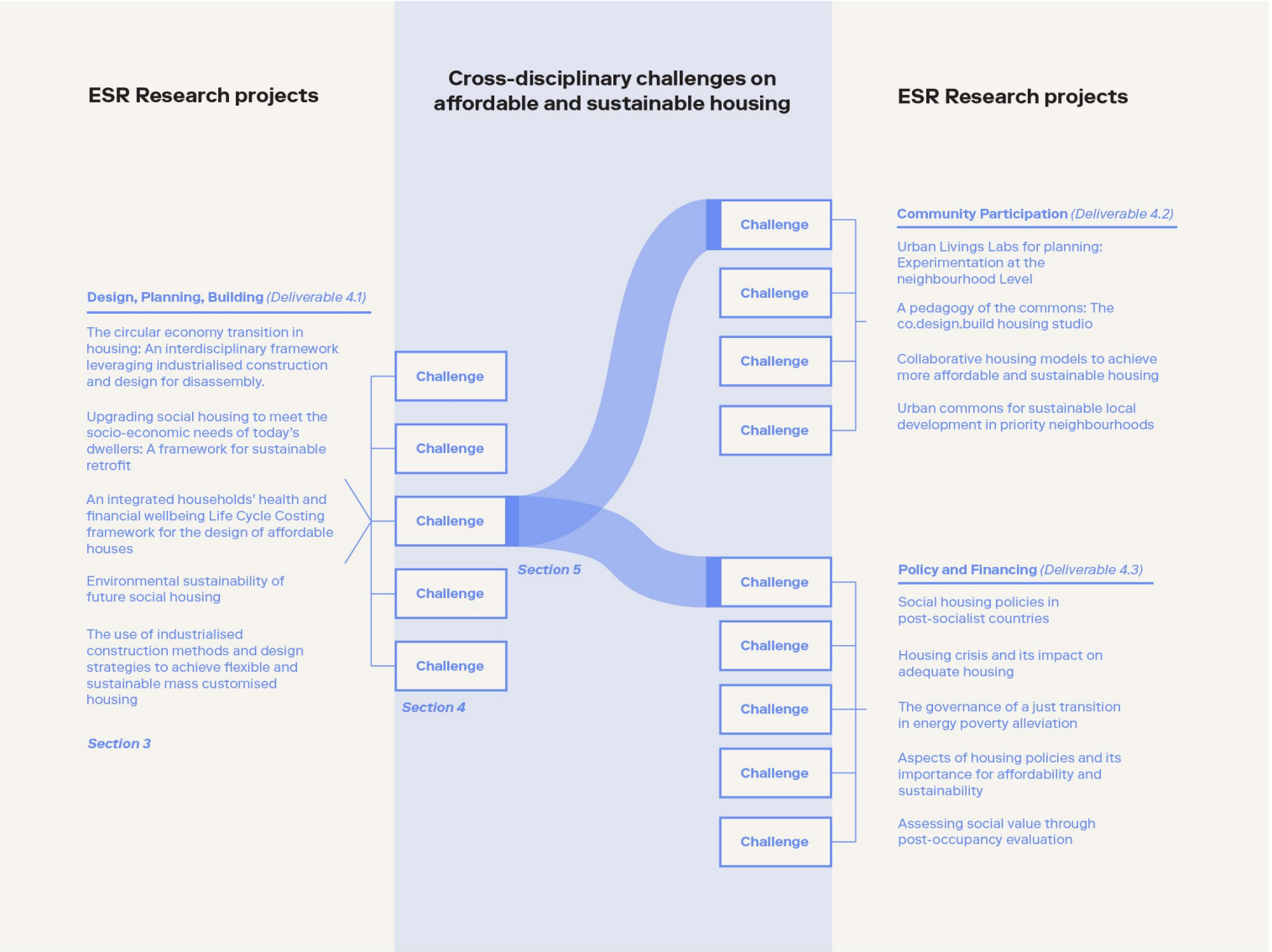

Figure 3. Working process and structure of the report

3. Research projects

In this section, each of the five early-stage researchers focusing on “Design, Planning, Building” provides a summary of their research work and synthesizes the literature review on the key topics related to it.

3.1. The circular economy transition in housing: An interdisciplinary framework leveraging industrialised construction and design for disassembly

by Annette Davis (ESR1)

3.1.1. Research project

The current lack of sustainable and affordable housing is a global issue which has reached a crisis point. The negative environmental impacts of the energy and materials consumed during the whole life cycle of housing is generally not considered, whilst in terms of affordability there is a lack of social and affordable housing for growing urban populations. Furthermore, residential buildings account for an average of 75% of the EU building stock, making the role of housing in the twin crises even more critical.

An important issue when addressing these challenges is resource inefficiency in housing, given that construction alone contributes to nearly 40% of global energy-related CO_2 emissions; as half of the world's materials are extracted for the building industry and over a third of all waste in the EU is generated by construction and demolition. Transitioning to the circular economy can improve both environmental sustainability and the affordability of housing in the long term. Designing buildings to be disassembled plays an instrumental in realising the circular transition, however, it is rarely fully implemented in permanent housing.

This project responds to a lack of knowledge and guidance for industry stakeholders to achieve 'circular' social and affordable housing at the building scale by providing practical evidence-based information centring on two key approaches: industrialised construction (known as Modern Methods of Construction in the UK) in combination with design for disassembly.

Research questions

1. What is the interrelation between Industrialised Construction and Design for Disassembly, and how do these concepts contribute to the principles of circularity in housing?
2. Which key processes define circular activities during the lifecycle, and which barriers and enablers arise during these processes which can then define the factors affecting implementation?
3. How do fundamental circular theoretical assumptions building in parts and layers impact the lifespan of buildings and the resulting embodied carbon?
4. What insights can be gained into the (dis)assembly and reassembly processes from the Solar Decathlon competition?
5. How do stakeholders from industry and governmental institutions in the UK, the Netherlands, and Spain perceive these barriers and enablers?

Expected outcomes

The proposed project outputs aim to inform designers, contractors, housing providers, and local-level policymakers on best practices for implementing circular principles based on industrialised construction in combination with design or disassembly to reduce carbon emissions and increase the longevity of housing. These outputs will include: (1) a circular process framework and (2) interdisciplinary guidelines covering the "dos and don'ts" of circular construction. The outputs draw on the findings from a systematic literature review, life cycle assessment study of a case study house, off-site factory and on-site disassembly/reassembly observations, interviews with industry experts and policymakers, and interdisciplinary workshops to validate the outputs.

3.1.2. Literature review

The current lack of sustainable and affordable housing is a global issue which has reached a crisis point. The negative environmental impacts of the energy and materials consumed during the whole life cycle of housing is not generally considered, whilst in terms of affordability there is a lack of social and affordable housing for growing urban populations (Tsenkova, 2022).

The transition to a circular economy can improve the environmental and economic sustainability of housing in the long term and ensure housing stock is adaptable (EMF, 2015; Pearce & Turner, 1990). Due to these advantages, there are an increasing number of environmental, financial, and political initiatives pushing the agenda in Europe. These include the European Green Deal, the Circular Economy Action Plan (European Commission, 2020), The Waste Framework Directive, and Level(s) sustainability framework, all of which rely on the disassembly and reuse of building parts being physically possible.

While building of any kind remains fundamentally in conflict with environmental sustainability—threatening to exceed carbon limits (IPCC, 2022; zu Ermgassen et al., 2022)—there is still a great demand to build additional housing for growing populations, particularly in cities. There are currently subsidy schemes in Europe (such as in the UK, the Netherlands, and Scandinavia) to promote industrialised construction (IC) in housing to manufacture millions of homes that are pre-built in off-site factories and assembled on-site (Bertram et al., 2019). This is advantageous as industrialised construction principles such as standardised and dry construction are key to enabling future disassembly.

Despite housing being more commonly prefabricated and assembled, alongside the requirement for material reuse for the circular economy to function, disassembly is not commonly integrated in the provision of permanent housing. Social and affordable housing are well suited to both industrialised construction and design for disassembly largely due to the potential to standardise on a mass scale. The ownership of social housing by institutions such as local authorities and housing associations is particularly advantageous to safeguard the long-term maintenance and circulation of materials.

The literature review highlights an overview of some of the fundamental concepts and challenges associated with circularity in the construction industry. It should be noted there is a general lack of application of these concepts to social and affordable housing within the literature.

- Defining circularity and embodied carbon: One of the foundational challenges lies in the ambiguity surrounding circularity metrics across industries and stakeholders. A unified definition with agreed-upon metrics is imperative (Kirchherr et al., 2023). Similarly, while embodied carbon can be precisely measured, regulatory oversights are still common in many countries, highlighting the need for standardisation.
- Economic incentives and taxation shift: Economic considerations significantly impact the adoption of sustainable practices. Circular construction and bio-based materials, while environmentally friendly, often incur higher costs. Shifting taxation from labour to resources could enhance the attractiveness of these solutions (Stahel, 2010). In the UK, the current 20% VAT levy on reuse and refurbishments compared to exemptions for demolition or new-build projects undermine decarbonisation efforts.
- Lack of local supply chains: The absence of localised industries poses a significant challenge. In particular, the production of carbon sequestering materials such as mass timber is mostly limited to Scandinavian countries. Creating local industries and using existing on-site materials promotes sustainability by minimising embodied carbon due to transportation.

- Early interdisciplinary engagement: Early collaboration between demolition teams, contractors, and designers holds the key to cost-effective solutions. Furthermore, demolition companies should provide disassembly teams to minimise destruction and increase reuse.
- Need for flexibility: The design, budgeting, and scope definition lack flexibility. These should not be fixed to enable the testing of new innovative product and construction methods.
- Need for auditing: Pre-redevelopment a pre-demolition audits facilitate knowledge transfer and promote reuse (GLA, 2022), though these are yet to be standardised.
- Legal classification of waste: Challenges arise from legal issues surrounding the classification of on-site materials marked for demolition as waste. As a result, current regulations act as a barrier, restricting the potential reuse of these materials.
- Procurement not conducive to circularity: Contractors are not incentivised to incorporate reuse and accept a higher level of risk. Tender documents should state clearly at the beginning of documents the requirement for second-life materials.
- Difficulty re-warrantying: More protocols and standardisation is needed to speed up the warranty process, testing is currently time consuming and prohibitively expensive.
- Material passports: Material passports are vital during disassembly (Atta et al., 2021) but require a balanced approach as to the type and level of detail information.

A lack of long-term thinking and application of industrialised construction in combination with disassembly could repeat mistakes akin to the prefabrication of poor quality post-war housing on a mass scale today. Not only do current practices perpetuate the destructive demolition of housing; plans to produce a large volume of prefabricated new homes and modular renovations could result in wide-scale demolitions in the future when housing is no longer fit for purpose due to changes in policy. There is therefore a great need for buildings to be designed and manufactured to be dismantled in the future to deal with changing needs, particularly in the face of the predicted increase in extreme weather events and changes in temperature that will require more building repairs and adaptations (Eurostat, 2020; IPCC, 2022).

Addressing the challenges identified in this literature review can pave the way for a more circular housing stock that takes a whole life cycle approach, improving both the environmental sustainability and economic viability of housing in the long-term.

3.1.3. References

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3.2. Upgrading social housing to meet the socio-economic needs of today's dwellers: A framework for sustainable retrofit

by Saskia Furman (ESR3)

3.2.1. Research project

European social housing peaked in the post-Second World War period. Predominantly designed and constructed by industry professionals—including architects, planners, engineers, and policy makers—the sector has suffered widespread disrepair due to deregulated building standards, poor maintenance, and lack of investment. Issues including poor insulation, inadequate energy performance, thin walls, cold conditions, dampness, and mould contribute to the desperate need to retrofit. Social housing residents typically lack the financial means or autonomy over building repair and maintenance, while building owners favour top-down retrofit decision-making processes that often neglect inclusive stakeholder engagement. Rather, living standards and conditions are imposed onto marginalised groups without integrating their needs, resulting in outcomes that are unfit for purposes.

Residents are experts in the way they live and should be key stakeholders in retrofit design. Non-energy benefits are more important to residents than energy-related benefits, particularly for social housing dwellers who require pragmatic solutions that differ from homeowners. Despite this, the prioritised method of deep energy retrofit (DER) favours three technical improvements: (1) enhancing the building fabrics' thermal properties; (2) improving systems efficiency; and (3) renewable energy integration. However, performance gaps can be as high as five times the predicted energy consumption, driven by the rebound and prebound effects, occupant behaviour, improper installation, and simulation uncertainties. Integrating residents' perspectives in retrofit design, alongside expert input, can help achieve sustainability objectives—social, environmental, and economic—by increasing energy performance, affordability, health and wellbeing, quality of life, and user empowerment.

Research questions

1. Could the participation of people living in social housing improve retrofit solutions more than end point performance targeted retrofitting?
2. How can social housing retrofitting be safeguarded for future tenants?
3. Is Deep Energy Retrofit (DER) the best approach for holistic sustainability?
4. What do inhabitants consider as important in retrofit, that is not included in the retrofit energy process?

Expected outcomes

The project will explore the sustainable upgrading of existing social housing stock in line with the triple bottom line of sustainability, prioritising social and environmental improvements and touching on the economic. From the results, a good practice guide for high level stakeholders to engage social housing residents in retrofit decision-making will be developed.

3.2.2. Literature review

The current research on engaging stakeholders in social housing retrofit can be classified into three scales: macro, meso, and micro.

Macro-scale challenges

Challenges at the macro-scale transcend individual projects and impact the overarching strategies and approaches to social housing retrofit initiatives. They include project funding, energy performance certificates (EPCs), and supply chains.

Project funding for social housing retrofit can support building owners and retrofit stakeholders by offering guidelines and case studies for good practices (Gov.uk, 2023a), alongside financial support. Funding obligations, however, can also introduce operational problems. Fylan et al. (2016, p.192) identify three key challenges: (1) timescales—funding applications must move quickly and spending deadlines are tight, constraining housing companies from providing adequately considered programmes; (2) the need for more control—control over allocation of funds would enable housing companies to tailor retrofit to the specific needs of a development; (3) conflicts of interest—energy company obligations can encourage suppliers to develop products more suitable to affluent homes, and different priorities within local authorities can hinder planning permissions. Furthermore, while much of the research confirms that residents are experts in how they live and occupy their homes (Awwal et al., 2022; Boess, 2022; Gianfrate et al., 2017; Lucchi & Delera, 2020; van Hoof & Boerenfijn, 2018; Walker et al., 2014), funding obligations make resident engagement in social housing retrofit extremely difficult to achieve due to lack of time, flexibility, and priority.

Energy performance certificates (EPCs) serve as a performance metric at the forefront of funding obligations, such as the UK's Social Housing Decarbonisation Fund (SHDF) and the EU's Next Generation Funds (NGF). EPCs can be used as a measure of success and to identify projects for retrofit, as with the SHDF which is targeted to social housing below EPC-C (Gov.uk, 2023b). Other legislation and directives including the EPBD (European Commission, 2021, 2024) also rely on EPCs as a key tool for improving buildings' energy performance and increasing their retrofit rate. EPCs for retrofit design have been criticised by González-Cáceres et al. (2022) because: they are primarily designed for new buildings and their adaptation for existing buildings is limited; and the required data for calculations are often unavailable, therefore based on guesswork or standardised values. In addition, EPC assessments do not analyse the condition of installed energy-related features, such as double glazing, and the sole reliance on EPCs can lead to low quality assessments and poor renovation recommendations (Bright et al., 2019; González-Cáceres et al., 2022). This overreliance on EPCs as a performance metric for retrofit can lead to incorrect energy savings and payback period calculations, leading to a performance gap.

A further macro concern of retrofit is supply chain uncertainty. Putnam and Brown's (2021) UK investigation into grassroots retrofit identified underdeveloped supply chain issues as a barrier to retrofit, due to market instability, poor demand "partly due to inconsistent and ineffectual public engagement programmes" (p.3), inconsistent policies, and contractors' reluctance to invest in new skills and methods without tangible benefits. Supply side issues will, in turn, reduce consumer uptake of retrofit (O'Keeffe et al., 2016).

Meso-scale challenges

Social housing retrofit challenges at the meso-scale level encompass issues that operate at an intermediate level of organisation and influence in the context of retrofit projects. Once a retrofitting project has been identified, development and implementation must consider three main issues: the building infrastructure, skilled labour, and engagement infrastructure.

A key challenge of social housing retrofit is the incompatibility between passive design techniques used in historical architectural vernacular and the active mechanical systems advocated for achieving energy efficiency requirements. Popular deep energy retrofit (DER) schemes such as EnerPHit (Grecchi, 2022) promote three main technical improvements: increased thermal properties with thermal insulation and airtightness; efficiency of systems such as heating and lighting; and installation of renewables (Institute for Sustainability & UCL Energy Institute, 2012). DER combines all available energy efficiency technologies to reduce energy consumption by 60%-90%, compared with pre-retrofit energy performance (Fawcett, 2014; Femenías et al., 2018). However, these whole-house (Jones et al., 2013) DER schemes and affiliated energy audits often neglect passive strategies that attempt to control comfort without consuming fuel, in part because mechanical systems can better predict, monitor, and evaluate building performance, helping to reach end point performance targets (Boess, 2022; Hoppe, 2012; Gianfrate et al., 2017; Walker et al., 2014). Passive strategies such as winter gardens, Trombe-Michel walls, blinds, and window operation can significantly reduce energy consumption (Gianfrate et al., 2017) but are difficult to accurately predict, measure, and evaluate successful energy performance. Correct use of passive strategies should be further explored and supported, rather than replaced, by mechanical systems.

A lack of skilled labour in the retrofit sector poses a significant challenge. Retrofit demands specific expertise distinct from new construction, requiring skilled workers who can navigate complex technical systems, including internal and external wall insulation, to meet required standards and avoid complex issues (Fylan & Glew, 2022). Retrofit projects also demand distinct people skills, particularly when work occurs in occupation. Effective communication between contractors and residents is vital, necessitating a unique set of person-centred skills. Technical errors and poor communication can increase performance gaps due to take-back and rebound (Boess, 2022; Gianfrate et al., 2017; Walker et al., 2014). Technical errors also lead to time and cost-intensive error-searching processes (Boess, 2022; Walker et al., 2014). Further expertise is required in demolition, essential to preserving materials and preventing unnecessary waste.

The active involvement of households is key to the adoption of residential retrofit measures (Ambrosio-Albala et al., 2020) and their correct use by dwellers (Gianfrate et al., 2017; Lucchi & Delera, 2020; van Hoof & Boerenfijn, 2018; Walker et al., 2014). However, barriers to household engagement remain a challenge. Difficulties convincing households to participate can lead to delays and rising costs (Hoppe, 2012), as well as misunderstandings (Gianfrate et al., 2017), mistrust and miscommunication (Gustavsson & Elander, 2016), and misuse of technology (Boess, 2022). When resident feedback is not integrated during the design phase, consequences include construction changes, cleaning and maintenance issues, inconvenient product placement, and lack of user-awareness (Boess, 2022; Gianfrate et al., 2017; Walker et al., 2014) which can result in performance gaps. Nevertheless, building owners, funders, and other retrofit stakeholders need convincing that prioritising early resident integration can save time and money at the end of a project (Boess, 2022).

Micro-scale challenges

At the micro-scale, the challenges of social housing retrofit are closely tied to individual projects and specific aspects of retrofit initiatives. There are three main challenges that operate at a localised level and focus on the intricacies of accommodating residents' needs, cultural diversity, and level of participation.

Safeguarding the needs of existing residents as well as future residents is a further challenge. Efforts to stimulate vibrant and adaptable communities should be considered throughout retrofit design and completion (van Hoof & Boerenfijn, 2018). Retrofitting without safeguarding measures can lead to increased mistrust and the displacement of low-income residents due to rising rents, unsuitable housing conditions, and changes in the socio-economic status of new occupants (Gustavsson & Elander, 2016). To effectively safeguard resident needs, it is essential

to identify the specific social challenges targeted by retrofit projects and tailor the process accordingly.

Accommodating the diverse cultural needs of social housing residents in retrofit design is a complex issue, requiring resident involvement, consideration of user habits, and promotion of social mixing, while recognising the importance of racial diversity (Awwal et al., 2022; Boess, 2022; Gianfrate et al., 2017; Lucchi & Delera, 2020; van Hoof & Boerenfijn, 2018; Walker et al., 2014). Understanding residents' needs and energy use patterns before and during retrofit design can lead to energy behaviour changes (Gianfrate et al., 2017; Boess, 2022; Walker et al., 2014). However, Walker et al. (2014) found that material changes alone did not significantly alter resident behaviour, highlighting the need for socially inclusive design that considers the diverse needs and habits of different social groups. Social mixing policies between different cultures and socio-economic residents have often failed to address social inequalities and discrimination (Gustavsson & Elander, 2016), emphasising the need to support social mixing with further measures (Gustavsson & Elander, 2016; van Hoof & Boerenfijn, 2018). Recognising the cultural diversity within social housing and enhancing its standards can improve the lives of residents, avoid imposing ideals on low-income individuals (Lucchi & Delera, 2020), and foster collective socio-economic growth (Gustavsson & Elander, 2016).

Limiting resident involvement to awareness campaigns focused solely on teaching residents how to use pre-designed systems is unlikely to drive meaningful behavioural change or effectively address performance gaps (Boess, 2022; Gianfrate et al., 2017; Walker et al., 2014). Similarly, 'tokenist' (Mjörnell et al., 2022) participation, where residents have limited decision-making power, may neither enhance energy-use behaviour nor foster a sense of ownership (Gustavsson & Elander, 2016; Mjörnell et al., 2022). To achieve lasting impact, information campaigns should complement more integrated forms of resident participation, involving them in decision-making processes early in the retrofit project to alleviate concerns, promote engagement, and reduce distrust (Hoppe, 2012).

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3.3. An integrated household health and financial wellbeing Life Cycle Costing framework for the design of affordable houses

by Aya Elghandour (ESR4)

3.3.1. Research project

The World Health Organization (WHO) underscores the profound influence of housing conditions on human health and wellbeing. Vulnerabilities to health risks and financial disparities intensify among low-income households living in ostensibly affordable homes, which, despite their affordability, often suffer from poor conditions. These might include being excessively cold and costly to heat during winter, lacking adequate ventilation, thereby promoting dampness and mold growth, or prone to overheating in summer.

Poor house conditions reflect poor building performance. They signal the need to prioritize households' health and wellbeing, starting from decision-making during the design stages. Those decisions can influence a house's future performance, impacting households' physical and mental health, referred to as “Health” in this study. It also affects future costs, including running and maintenance, thus impacting households' “Financial Wellbeing”.

Therefore, the study advocates rethinking the concept of designing and constructing affordable dwellings to be affordable from both the perspectives of households' health and financial wellbeing (H+FW) and housing providers' long-term investment. Balancing these perspectives is a recognized challenge. To address this, the study proposes using Life Cycle Costing (LCC) from the design stages of affordable dwellings. LCC is an economic analysis method that supports cost allocation decisions by adopting long-term thinking, allowing stakeholders to predict the overall costs of a project over a specific period.

This research aims to develop an LCC framework for the design stages, integrating households' H+FW considerations. It is structured into four phases. The first phase adopts a transdisciplinary approach through a (1) secondment within a non-academic British housing association to understand housing providers' perspectives on facilitating affordable homes and (2) conducting semi-structured interviews with professionals from various regions in England, covering architecture, affordable housing provision, and public health. The second phase will identify tangible components contributing to H+FW within a house to develop a taxonomy. In the third phase, the study will propose a novel H+FW LCC framework tailored to the British context and adaptable to other European countries. The fourth phase involves testing and validating the framework through case study analysis. This analysis will examine two design scenarios of a house in Sheffield using Building Information Modelling (BIM), Building Performance Simulation (BPS), and LCC.

The framework will serve as a valuable decision-making tool for designing affordable and healthy houses, considering perspectives from both housing providers and households. Additionally, it will help identify key stakeholders whose decisions in the design stages influence the future dwelling's impact on households' H+FW. Moreover, it will offer valuable guidance by considering not only initial construction and operational costs for housing providers but also the long-term implications for households' health and financial wellbeing.

Research questions

1. How can LCC integrate households H+FW in the design stages of affordable houses?
2. What decisions are made during the design stages of affordable housing that could impact households' H+FW in the future? Moreover, who makes those decisions?
3. What are the life cycle costs of an affordable house?
4. Which house characteristics promote households' H+FW?

Expected outcomes

- A novel H+FW LCC framework tailored to the British context, adaptable to other European countries
- A taxonomy of Affordable House Characteristics Promoting Household Health and Financial Wellbeing
- Key stakeholders whose decisions influence the house's impact on households' H+W will be identified.

3.3.2. Literature review

Even though housing affordability contributes to household's H+FW, the design and construction of affordable and healthy homes still encounter several challenges, including the following.

Housing providers being a key decision-maker. Housing providers and their financial decisions are vital in offering affordable, healthy, good quality, and sustainable housing (Gibb et al., 2020). Housing is also a real estate investment where decisions are heavily based on objective data analysis to ensure a profitability threshold is achieved (Ahmad & Thaheem, 2018). Achieving profitability margins may challenge balancing low construction cost expectations with health and sustainability goals in affordable housing. For instance, the Passivhaus standard prioritises low-carbon, low-energy, and indoor air quality measures, leading to substantial (80% to 90%) operational cost reductions for end-users (Schnieders et al., 2015). Despite these benefits, it is often considered expensive, possibly due to a 5% to 10% increase in construction costs (Forde et al., 2020). This dilemma may lead many to prioritizing initial construction costs cuts over the future comfort of the home, quality of life, and housing sustainability (Brysch & Czischke, 2021; Cambier et al., 2021).

Affordability being too complex to include in design stages. Housing affordability is complex, and predicting it during the design stages is difficult. Common methods of measuring housing affordability rely heavily on economic aspects such as the Income Ratio Method (IRM) and the Residual Income Method (RIM) (Ezennia & Hoskara, 2019; Haffner & Heylen, 2011). IRM refers to the ratio between rent and income not to exceed a certain percentage, while RIM is the remaining income after subtracting housing costs – rent or mortgage - to reflect households' ability to afford their non-housing expenditures (Stone et al., 2011; Stone, 2006). However, without proper space or quality standards, there is a risk that affordability perception may endorse policies that tolerate unfit properties just because they are affordable (AHC, 2019). Despite the recognition of the importance of housing quality in providing affordable housing (Ezennia & Hoskara, 2019; Haffner & Heylen, 2011; Leviten-Reid et al., 2020; Stone, 2006), there are still risks of poor quality, housing deprivation, and contributing to social injustice, health injustice, poverty, and fuel poverty (Garnham et al., 2022).

The subjectivity of housing affordability and housing quality. Risks also emerge from the subjective perception of housing affordability and housing quality. At a national level, affordability can be influenced by economic and social circumstances (OECD, 2021). For example, a house cannot be considered affordable if it is low-quality, unhealthy, and located in

insecure, deprived areas that lack access to good education and essential amenities. (Holding et al., 2020; Leviten-Reid et al., 2020). Such situations provoke "residential segregation" (Adabre & Chan, 2019; Salvi del Pero et al., 2016) and intensify gaps of social and health injustice, poverty, and fuel poverty (Barker, 2020; Garnham et al., 2022).

From a household perspective, affordability and quality concerns vary. A study on residents' decision-making to build affordable collaborative housing found that they prioritised incomplete finishes, sacrificing some appliances, and smaller room areas while prioritising energy efficiency measures (Brysch & Czischke, 2021). Although energy concerns contribute to long-term affordability, smaller room areas may contribute to overcrowding in certain contexts, posing risks to H+W (Baker et al., 2020). Moreover, poor quality affordable housing may suffer from hazards causing Sick Building Syndrome and other illnesses (Licina et al., 2021).

Poor housing harms households' health and wellbeing. Poor housing conditions harm households' H+W (Boomsma et al., 2017; Housing Europe, 2021; OECD, 2020). In England, poor-quality housing is estimated to cost the NHS £1.4 billion a year (Garrett et al., 2021). A shocking statistic in 2018, revealed that the inability to afford proper home heating led to the deaths of 17,000 people.(Centre for Ageing Better, 2021). Other conditions might encompass dampness from water incursion or poor ventilation; sources of infestation; inadequate electrical installations; lack of soundproofing; poor energy efficiency due to draughty windows and doors and insufficient insulation; poor heating systems, whether old or not functioning (Garnham et al., 2022). Additionally, dampness and mould trigger respiratory problems (Baker et al., 2020; Howden-Chapman et al., 2012; Liddell & Guiney, 2015). Overheating, exacerbated by global warming, poses risks to older individuals (Baborska-Narozny et al., 2017). These issues worsen housing stress and mental health in low-income households due to recurring maintenance costs (Holding et al., 2020; Robinson & Adams, 2008; Boomsma et al., 2017).

The complexity of integrating LCC and Building Performance Simulation (BPS) to design affordable and healthy houses. In the design stages, decision-making can mitigate threats to household H+W by utilising Building BPS and LCC to predict future house performance and the costs of different design alternatives (Goh & Sun, 2016; Han et al., 2014; Karatas & El-Rayes, 2014; Seminara et al., 2022). Ignoring future building performance and future costs may lead to inefficient decisions in the design stages, increasing future costs and harming house quality (Gluch et al., 2018; Zanni et al., 2019), and its affordability. However, research on the integration of LCC and BPS in design stages revealed some difficulties, namely:

The use of LCC to benefit end-users might not be the case when incorporated into residential projects. LCC calculations might exclude expenses paid by residents. LCC is often used to provide insights on the economic feasibility of building ownership as capital, where the occupation and running costs paid by end users are often excluded (RICS, 2016). Even though social sustainability contributes to H+W, it has received little attention when using LCC to support the design of the house itself (Ahmad & Thaheem, 2018). One study incorporated aspects of healthy building, such as indoor air quality and toxicity of materials, among others, following a proposed sustainability assessment criteria to be achieved with the help of LCC (Jalaei et al., 2015). On the contrary, a large number of studies used LCC to promote economic and environmental sustainability and dwelling energy efficiency (Ahmad & Thaheem, 2018; Fantozzi et al., 2019; Hajare & Elwakil, 2020; Rad et al., 2021; Schmidt & Crawford, 2018).

Integrating LCC and BPS for design purposes poses several challenges, both in terms of data and the process itself. One of the significant issues is the inaccessibility of reliable and accurate cost and performance data (Goh & Sun, 2016; Schmidt & Crawford, 2018), which may constantly change, such as household energy consumption and energy costs (Hajare & Elwakil, 2020). Another issue is data interoperability, which can be time-consuming, especially when corresponding modifications are necessary (Carvalho et al., 2021).

Regarding the process, the absence of a standardised LCC framework for housing projects might hinder the comparison of different design alternatives or housing projects (Islam et al., 2015). The preparation for this process involves various tasks, including identifying multiple performance evaluation criteria, establishing thresholds, determining ideal values, and implementing a normalisation process (Ahmad & Thaheem, 2018).

In sum, overcoming these challenges demands interdisciplinary collaboration and a comprehensive approach to ensure housing decisions positively impact H+FW without compromising affordability or quality.

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3.4. Environmental sustainability of future social housing

by Mahmoud Alsaeed (ESR5)

3.4.1. Research project

Environmental sustainability and social housing are important issues that are intertwined and hindered by unsustainable practices in the design, construction, and operation of housing. Social housing has a significant value in the UK, forming up to 18 per cent of the total housing stock, which accounts for 5.3 per cent of national energy consumption and contributes to 3.6 per cent of housing sector carbon emissions. To address these complex and interlinked issues, the UK government has launched multi-faceted strategies, including the ambitious target of achieving net zero emissions by 2050 and a decarbonised housing sector by 2030. At the same time, mandatory and voluntary sustainability standards and a reformed housing policy have been adopted to support the achievement of these targets. However, critical assessments in recent Environment Committee reports have shown that progress towards these national targets has been very slow. This lethargic progress is attributed to several obstacles. These include complicated and fragmented regulations and procedures, a pervasive lack of clarity among industry professionals on environmentally sustainable social housing, and a vague path towards energy efficiency and carbon neutrality.

The core aim of this research lies in the overarching intention to question and subsequently reform existing paradigms of practice that are perceived as ineffective due to their complicated and fragmented nature. The necessity for an innovative, realistic, and straightforward framework for the development of sustainable social housing is, therefore, a crucial element in addressing the prevailing issues.

This project relies on a qualitative study as its methodological foundation, facilitating the primary conceptualization of sustainability and housing policies, their developmental trajectories, and the application of a methodology for measuring environmental sustainability in social housing. This investigation is complemented by various methods, such as semi-structured interviews with key stakeholders, including housing associations, sustainability specialists and architects. These interviews provide important insights into prevailing practices within the field, informing the in-depth analysis of three case studies on sustainable social housing practices.

Research questions

1. What standards for environmentally sustainable social housing are needed to promote simple and effective practices?
2. What is the current perception and structure of housing and sustainability practices?
3. How do we define and measure the environmental sustainability of housing?
4. What tools can be used to achieve an efficient and environmentally sustainable housing sector?

Expected outcomes

A policy and practice framework that addresses the environmental sustainability of social housing and provides practical design and planning guidance to achieve an environmentally sustainable social housing sector in the UK. This framework will be significant for its potential to trigger nationwide change, support practical developments in housing sustainability and encourage future studies into achieving sustainable social housing through simplified and effective codes and standards.

3.4.2. Literature review

In 2021, there were 4.4 million social housing units in England, and this is projected to increase rapidly in the upcoming decade. Concurrently, social housing consumes up to 5.3 per cent of the country's energy causing 3.6 per cent of carbon emissions (DBEIS, 2020). Consequently, creating environmentally sustainable housing within the confines of available natural and energy resources has become an imperative (HE, 2023). However, there are ongoing impediments to the construction of environmentally sustainable social housing, where there is a lack of operational understanding of what sustainable social housing means particularly relating to its concepts, structures and challenges This brief literature review attempts to highlight the key challenges facing the provision of sustainable social housing in Europe.

The misconception in the narrative of sustainable social housing

When examining the narrative of sustainable housing, the misconception of what social housing is and its sustainability arises as a key challenge and is evident at two levels. First, there is the broad debate on housing, which encompasses housing as a material, as an activity, and, as Aalbers (2018) suggests, as an 'environment' which includes housing policy, social values and the welfare state, among many other issues (Aalbers, 2018; Ruonavaara, 2018). Defining the meanings and requirements of social housing seems to be a straightforward task. Yet, there is no clear and well-established definition that encompasses all elements or concerns of all schools of thought on housing and social housing (Clapham, 2018). The second level concerns the perception of developing sustainable social housing, where the concept itself draws from various origins and is influenced by numerous other concepts and theories (Oyebanji, 2014). However, there is a lack of a precise definition that clarifies the interconnectedness of the main concepts involved and their challenges. Both levels have direct implications for the delivery of sustainable social housing. As Renukappa et al. (2012) explain, there is a significant lack of shared understanding of sustainability and many misconceptions about what sustainability means for the UK housing sector (Renukappa, Egbu, Akintoye, & Goulding, 2012).

On the other hand, the work of Carter & Fortune (2007) has highlighted the massive gap between sustainability standards and the actual perceptions and practices of professionals involved in developing sustainable housing. These misconceptions have contributed significantly to stakeholders holding opposing views and consequently rejecting the fundamental idea of sustainability (Renukappa et al., 2012). This was also evident in the Environmental Audit Committee report Housing: Building a Sustainable Future published in 2005, which found that more than 30 per cent of new housing did not meet building regulations, particularly sustainability requirements (EAC, 2005; Pickvance, 2009).

Measuring the sustainability of social housing

Measuring sustainability is key to monitoring development progress towards meeting the intended agenda. However, the current process is a complex task for several reasons. First, the environment comprises complicated systems and interconnected processes, making it difficult to isolate specific factors and measure their individual impacts (Arjen, 2015; Berardi, 2012; James, 2014; Kubba, 2012). Moreover, environmental problems often extend over long periods of time, making it difficult to capture and assess the full extent of change and its consequences. Collecting accurate and reliable data on environmental indicators can also be a daunting task, as it often requires extensive research, monitoring and analysis (Poveda & Lipsett, 2011). In addition, stakeholders' different perspectives and values complicate the measurement process, as sustainability itself is a subjective concept that is interpreted differently (Oyebanji, 2014; Pickvance, 2009). Therefore, capturing the complexity of environmental sustainability requires robust methodologies and interdisciplinary approaches to ensure accurate and meaningful measurements.

Fragmentation and complexity of the current regulatory framework

Sustainable social housing progress is often measured through regulatory frameworks and professional practice. Regulatory frameworks are at the top of the planning pyramid and are often exemplified by national policies, building regulations and standards (Carter & Fortune, 2007). Pickvance (2009) stated that the complexity of current regulations has reached a level that cannot be fully understood, and that enforcement has become a burden for local authorities (Pickvance, 2009). The Environmental Audit Committee's 2013 report also concluded that sustainability regulations make house building unnecessarily expensive and complicated (EAC, 2013a), and require a complete review and restructuring to simplify the "untenable forest of codes" (EAC, 2013b, p. 11). The Building a Safer Future report, commonly referred to as "The 2018 Hackitt Review of Building Regulations", added that existing building regulations, including those governing sustainability compliance, suffer from inadequacies, inconsistencies and lack of clarity (Hackitt, 2018). Recently, the Committee on Climate Change's 2019 report reached a similar consensus, finding that the UK's current housing stock, policies and practices are ill-suited to the future envisaged by the government. Therefore, the quality, design and use of housing across the UK must improve rapidly to meet the challenges of climate change (Holmes et al., 2019).

Need of innovative strategies in today's practice

The current provision of social housing requires a proactive and innovative strategy to achieve sustainable development objectives. Bakar et al. (2009) explain that any social housing provider must strive for effectiveness as the UK market is competitive, and best practice in this case is the accurate and successful implementation of a clear, sustainable strategy. In addition, developers must consider existing national plans and policies (Bakar, Razak, Abdullah, & Awang, 2009). Several scholars have raised questions about existing practices in social housing development, especially sustainability. in addition, the absence of 'need assessment stage' may mean that the full extent of housing needs is not accurately captured, particularly for vulnerable groups (Bramley & Karley, 2005). Scholars such as Arthurson et al. (2004) add that other factors also impact sustainable social housing development, such as the process of selecting suitable sites. which can perpetuate social segregation and concentrations of poverty (Arthurson & Jacobs, 2004). Additionally, the planning permission stage has been criticised for its bureaucratic nature and possible delays (Whitehead, 2007). Likewise inadequate funding which leads to a lack of affordable housing (Arthurson & Jacobs, 2004; Coscia, Mukerjee, Palmieri, & Quintanal Rivacoba, 2020; Oxley, 1999).

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3.5. The use of industrialised construction methods and design strategies to achieve flexible and sustainable mass customized housing

by Carolina Martin (ESR14)

3.5.1. Research project

Mass Customisation (MC) is a broad term that has been in constant evolution since it was first introduced by Stanley Davis in his book Future Perfect, published in 1987. MC is a process by which a company approaches its production in a customer-centric manner, developing products and services according to the needs and requirements of each individual customer, keeping costs near to mass production. This concept is strongly linked to the Open Building theory that emerged during the 1980s, influenced by the work of Habraken (1976), who envisioned dwellings as continuously evolving entities with elements grouped into different control levels. This approach allows participation and freedom of choice by all involved in their design and construction, including residents. Industrialised Construction (IC) methods have the potential to leverage mass production techniques, optimising processes, standardising components, and achieving economies of scale.

Today, the existing housing stock does not respond to the varied needs of the current households, nor is it resilient enough to adapt to the future ones. Promoting mass customised housing involving all stakeholders in the process would result in a much more valuable, adaptable, and sustainable built environment. This flexibility can support long-term affordability by allowing homeowners to modify their homes rather than moving or undertaking costly renovations. It can also contribute to environmental sustainability by reducing waste and promoting an efficient use of resources. While mass customisation is a practice that has been implemented in other manufacturing industries and in the single-family housing market, it has not yet been implemented into multifamily housing. In particular, there is a lack of research on how to develop a product platform that aligns the variety of building products to the variety of needs, based on different degrees of customisation. This is partly due to the lack of component standardisation, the slow digital integration, and the short-sighted strategies of the construction industry.

Setting up a product platform is one of the operational challenges a construction company must address to establish as a mass customiser. Many studies have examined how the location of the decoupling point in the value chain plays a decisive role in defining the level of customisation offered and, consequently, the manufacturing strategy of a product platform. Additionally, it has been observed that one of the elements hindering process optimisation is the stratification and segregation between the different disciplines in the building industry. Therefore, a product platform should be the result of a fruitful, ongoing communication between the user's needs, the internal capabilities of the IC company, and all the stakeholders involved in the process.

This project will investigate the implementation of Mass Customisation (MC) in multifamily housing through product platforms. It will identify design strategies, Industrialised Construction methods, biggest challenges, and best practices. To achieve this, a comparative case-study of the multi-family projects nominated to the EU Mies awards during this century. The research will develop a combined assessment methodology integrating a taxonomic classification of building components and design strategies implemented at each building layer, along with the degrees of customisation it holds, identifying the level of customisation achieved. Subsequently, four multifamily housing projects from the European context with varying levels of customisation will be selected. Through an in-depth case study comparative analysis, the design flexibility, manufacturing efficiency and construction resiliency will be evaluated using a

holistic framework. This analysis will highlight major challenges in the design and construction processes and evaluate their kit-of-parts. Finally, a multi-criteria decision analysis (MCDA) method will be employed to evaluate and propose improvement strategies for implementing mass customisation in a multifamily housing project at Grupo Casais. Workshops involving different stakeholders will be used to evaluate the transferability of knowledge between disciplines and validate the proposed improvement strategies.

Research questions

1. Which aspects of the design, production, and assembly processes should be considered to facilitate the implementation of Mass Customisation for internal layouts in affordable and sustainable multifamily housing?
2. What is the relationship between an industrialised system of construction and the design strategies at each building layer, and how does it influence the degree of customisation for the interior distributions of multifamily housing?
3. How can the design flexibility, manufacturing efficiency, and construction resiliency of multifamily housing projects be evaluated through a holistic framework, employing a multi-disciplinary analysis of the building layers?
4. How can the level of customisation of the interior distributions of a multifamily housing project be evaluated and improved within an affordable and sustainable framework, using a product platform?

Expected outcomes

- Development of a framework with indicators to guide the implementation of mass customisation of housing internal layouts for various stakeholders in the construction industry.
- Creation of a combined assessment methodology integrating a taxonomic classification of building components and design strategies at each building layer, alongside the degrees of customisation they offer. Implementation of this methodology in the EU Mies Awards will highlight trends from past decades.
- In-depth analysis of the design flexibility, manufacturing efficiency, and construction resiliency of four case studies featuring different degrees of customisation. Comparison of four distinct Industrialised Construction (IC) building systems, along with discussion of bottlenecks, design processes, and technological enablers for each.
- Formulation of improvement strategies for implementing mass customisation in a multifamily housing case study at Casais. These strategies will undergo discussion and testing in workshops involving various stakeholders.

3.5.2. Literature review

In today's context, there is mounting pressure to provide housing that is highly responsive to the needs and desires of its residents, while also ensuring consistent quality and reduced environmental impact. This includes minimising energy consumption during both construction and operation, thereby lowering the lifetime carbon footprint. Architects and urban planners face the challenge of creating flexible and adaptable housing solutions amidst pressing issues such as climate change, unprecedented population growth, and housing affordability.

Mass customisation (MC) revolutionizes production by tailoring products and services to the unique needs of individual customers while maintaining costs comparable to mass production (Piller, 2004). Alvin Toffler initially introduced the concept in his seminal works, "Future Shock" (Toffler, 1970) and "The Third Wave" (Toffler, 1980). Stanley Davis later coined the term in his book "Future Perfect" (Davis, 1987) and Joseph Pine developed its practical application in business (Pine, 1993), leading to its growing significance in research and practice (Nahmens & Mullens, 2009).

Despite its potential benefits, some have noted challenges associated with customer participation (Veenstra et al., 2006), while others have developed methodologies and frameworks for its application to the housebuilding industry (Bock & Linner, 2013; Cao et al., 2021; Duarte, 2005; Friedman et al., 2013; Hentschke et al., 2020; Khalili-Araghi & Kolarevic, 2018; Lampel & Mintzberg, 1996; Mohamed & Carbone, 2022). Integrating MC into the housebuilding industry has the potential to democratise housing design, fostering empowerment, social enrichment, and cultural enhancement in our built environment, provided it is supported by robust technological and business foundations (Piller et al., 2005).

The successful adoption of the MC paradigm in the housebuilding sector could benefit from the adoption of Open Building (OB) principles (Kendall, 2021). The OB theory, influenced by Habraken's ideas, emerged in the 1980s, enabling dwellings to continuously evolve by organising their elements into different control levels, thus promoting participation and freedom of choice (Habraken, 1976). In light of the uncertainty surrounding future societal transformations, it is crucial for the built environment to possess flexibility and adaptability to accommodate potential needs of dwellers. Flexibility allows for easy rearrangements of a building's internal layout to suit changing occupant requirements, while adaptability encompasses designing for easy alterations to extend the structure's lifespan, such as adding or reducing space to accommodate new usage patterns (Schneider & Till, 2007).

Another vital aspect of MC is the product platform, which several authors have highlighted as one of the three operational capabilities essential for a company to become a mass customiser. The product platform, also known as the solution space, consists of a variety of different customisation units and the definition of rules to combine them, thereby limiting possibilities to establish a balance between productivity and flexibility (Larsen et al., 2019; Salvador et al., 2009). Furthermore, the level of customisation defines the boundaries of the product platform and significantly influences the level of customer integration, thereby determining the business model. This level of customisation can vary by adopting different Customer Order Decoupling Points (CODP) (Barlow, 1998; Schoenwitz et al., 2017; Smith, 2019).

Additionally, some scholars have emphasised the close relationship between MC and product modularity, recognising that standardising modular units of construction allows for the systematic combination of these units, leading to strategic flexibility and the ability to meet diverse needs without compromising efficiency. Product modularity within a product platform enables the design of a building in smaller subsystems that can function independently yet cohesively as a whole (Smith, 2011). Hence, MC can effectively be integrated into the housebuilding industry through the use of modular components that are interchangeable, autonomous, loosely coupled, upgradeable, and equipped with standardised interfaces

(Voordijk et al., 2006). By considering Habraken's control levels (Habraken, 1982) and Steward Brand's concept of shearing layers (Brand, 1994), the degree of freedom or flexibility in a platform can be expressed hierarchically through architectural objects, where higher-level objects constrain those at lower levels. Moreover, encapsulating functional and experiential product attributes, along with decoupling the modular design objects and system constraints, could support the spatial customisation of housing layouts. At a conceptual and strategic level, platforms have increasingly been embraced as a framework for addressing diverse challenges across various applications. 'Platform-thinking' enables businesses to gain competitive advantage through by creating new forms of value (Aitchison et al., 2018).

An industrialised approach to housing holds the promise of directly addressing contemporary challenges by advocating for open building systems, the use of biobased materials, modular coordination, and the adoption of innovative production technologies. Over the past decades, IC has proven its ability to facilitate customer-centric approaches, delivering flexible and customisable housing solutions while ensuring economic viability (Tanney, 2019). IC is a broad and evolving term encompassing innovative methods and processes that are revolutionising the construction industry (Lessing, 2006). Through its focus on a product-based approach, standardisation of components based on a kit-of-parts, and emphasis on feedback loops and flows of knowledge, IC represents a transformative shift in building design and construction, fuelled by advancements in fabrication and manufacturing technologies (Kieran & Timberlake, 2004). The advantages offered by IC include improved quality, accelerated construction times, cost reduction, waste minimisation, risk mitigation (including worker safety and weather-related delays), enhanced efficiency, and increased productivity. Additionally, the integration of emerging technologies such as Building Information Modelling (BIM) early in the design process can enable data-rich models to support more efficient processes, leveraging production and flexibility. Parametric tools also hold promise in ensuring that customised alternatives comply with manufacturing restrictions and regulations while optimising resource usage and shortening lead times (Piroozfar et al., 2019).

However, to overcome past failures and devise appropriate solutions for the future, it is paramount to adopt a holistic perspective that considers the complexity and constraints inherent in housing (Aitchison et al., 2018). The future trajectory of MC will necessitate a process of compromise and evaluation of trade-offs. It will entail striking a delicate balance between design flexibility and efficient production systems, carefully managed to enhance perceived value for residents without escalating costs and lead times. Moreover, this must be achieved while simultaneously enhancing build quality and meeting sustainability objectives.

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3.6. Key emerging issues on "Design, Planning, Building"

The previous summary of the research projects highlights several key themes that underscore the challenges of achieving sustainable and affordable housing.

A recurring focal issue is the global housing crisis, emphasizing the escalating demand for housing solutions that are both environmentally sustainable and economically viable. This commonality entails a collective recognition of the urgency to address the complex interplay between housing and residents' needs, environmental impact, and economic considerations.

Environmental considerations are prominent across the literature reviews, with an emphasis on the impact of housing life cycles. They also call attention to the need to adopt circular economies as a solution, aligning with global initiatives such as the European Green Deal. However, there are barriers including the absence of standardized circularity metrics, economic challenges hindering sustainable practices, and the need for local supply chains.

Housing providers' pivotal role in decision-making surfaces as a critical theme, with financial considerations often posing challenges in balancing construction costs with health and sustainability goals. The complexity of affordability, measured through methods like IRM and RIM, becomes evident, with potential trade-offs that may impact long-term housing quality.

Additionally, the subjective nature of housing affordability and quality introduces risks, contributing to social injustices and health issues. The integration of Life Cycle Costing (LCC) and Building Performance Simulation (BPS) in the design stages is recognized as a solution to mitigate risks associated with poor housing conditions. The limited attention to social sustainability in LCC and difficulties in obtaining reliable data, underlines the need for standardized frameworks and data accessibility in shaping housing design decisions.

Misconceptions surrounding the definitions of social housing and sustainability are recurring themes, fostering conflicting perspectives among stakeholders, and hindering the widespread adoption of sustainability principles. The measurement of sustainability in social housing is a complex task, marked by challenges such as the intricate nature of environmental systems, the extended timeframe of environmental issues, and the subjective interpretation of sustainability.

The regulatory framework governing sustainable social housing is criticized for its fragmentation and complexity, necessitating a comprehensive review to simplify the landscape. Inadequacies and inconsistencies in existing regulations, particularly those related to sustainability compliance, highlight the urgent need for improvements in housing quality, design, and utilization to meet the challenges posed by climate change. The ongoing scholarly research collectively calls for nuanced understanding, a comprehensive framework, accurate sustainability measurements, streamlined regulations, and strategic practices aligned with sustainability goals to address these fundamental barriers.

The retrofitting of social housing emerges as a multifaceted theme across different scales: macro, meso, and micro. At the macro level, the main issues identified are operational introduced by funding obligations, limitations of energy performance certificates (EPCs) as performance metrics, and supply chain uncertainties. Conflicts between passive and active retrofit techniques, a lack of skilled labour, and the importance of early resident engagement are identified in the meso-scale. On the micro scale, safeguarding residents' needs, accommodating cultural diversity, and ensuring meaningful resident involvement to drive lasting behavioural change are highlighted. Key issues include funding obligations, limitations of energy performance metrics, supply chain uncertainties, conflicts between retrofit techniques, and the necessity for early resident engagement.

Mass customization (MC), rooted in a customer-centric production approach, emerges as a strategy for tailored housing solutions while maintaining cost-effectiveness. The integration of MC into the housebuilding industry, coupled with Open Building (OB) principles and product platforms, is positioned as a means to democratize housing design, empower residents, and enhance cultural aspects. However, a need for a careful balance between design flexibility and efficient production systems is acknowledged. The industrialised approach to housing through Industrialised Construction (IC) emerges as a viable solution, leveraging kit-of-parts standardisation, innovative production technologies, and integration with Building Information Modelling (BIM). IC can offer benefits such as improved quality, faster construction, cost reduction, waste minimisation, and increased efficiency. The future trajectory of MC involves navigating compromises and trade-offs, balancing design flexibility with efficient production systems to enhance perceived value for residents, improve build quality, and achieve sustainability goals.

4. Challenges in "Design, Planning, Building"

The account provided in previous sections offers an overview of some key issues intertwining design, planning, and building, primarily from a scholarly perspective. However, a transdisciplinary approach to affordable and sustainable housing must encompass non-academic stakeholders who can contribute to identifying and solving housing problems with their knowledge and experience. This necessitates that researchers articulate their findings in language understandable to non-experts, facilitating dialogue with them.

With this purpose in mind, researchers were tasked with identifying key challenges in a manner that integrates issues from various experts on contemporary and affordable housing, making these challenges understandable to a broad audience. This exercise allows them to apply the knowledge acquired in the RE-DWELL courses dedicated to research methods and transferable skills.

The challenges presented in the following sub-sections are derived from the knowledge accumulated by researchers throughout their research journey, including secondments, courses, vocabulary, and case studies. These challenges encompass a variety of topics, such as energy poverty, building retrofitting, and social housing, spanning various dimensions—environmental, social, economic, and institutional—and operating at different levels, ranging from individual buildings to neighbourhoods, municipalities, metropolitan areas, and regions. They also involve different actors and apply diverse methods and tools.

These challenges are summarized in Table 2, which includes their connection with some of the framework components provided by the tripartite conceptual structure developed in Deliverable 4.6:

- Target knowledge (Topics, Dimensions, Levels)
- Systems knowledge (Tools, Methods, Actors)
- Transformational knowledge (Policies, Projects, Partnerships)

4.1. Integrating design for disassembly principles with industrialised construction practices to reduce the embodied carbon impacts of housing over the building lifecycle

Despite pervading obstacles in the adoption of industrialized construction in housing, there is a noticeable uptick in research and application in this field. While this trend is positive encouraging, it predominantly emphasizes building assembly, often overlooking future disassembly during the use or end-of-life phases. Moreover, there is a glaring lack of long-term vision and consideration for the whole life cycle of buildings and their constituent parts. Addressing these gaps requires the implementation of systems involving multiple stakeholders to facilitate the safe dismantling of building parts for reuse or upcycling, without causing damage to components or connecting parts.

4.2. Lack of early integration of resident stakeholders in housing retrofit which potentially yields benefits such as cost savings, reduced performance gaps, and increased social value

The challenge of housing markets inadequately meeting diverse housing needs is a multifaceted issue. Affordable housing is in short supply, impacting people across various income levels, with a disproportionate burden on low-income and marginalized communities. From an ownership and tenure perspective, private property is heavily favoured as the primary means of accessing housing, while alternative forms of collective ownership or use remain largely unexplored. Furthermore, the housing supply does not align with evolving demographics, leaving the elderly, young people, smaller households, and single individuals with limited options. Sustainability is another concern, as it is often approached from a techno-managerial standpoint rather than in relation to the unique ways of living within communities. Additionally, the prevailing housing typologies primarily promote individualized living, offering limited opportunities for social interaction, resource sharing, and collaborative everyday tasks. This situation inhibits the development of more communal ways of living. Housing created with the active participation of residents and a focus on community engagement is either lacking or inadequately supported by governments. Local advocacy has the potential to influence policymakers and foster housing diversity, but community participation is crucial.

4.3. The underutilisation of Life Cycle Costing (LCC) for households often leads to oversights in investing in tangible features that positively impact residents' health and financial wellbeing in the long term

When designing affordable homes, it is crucial to strike a balance between construction costs, future operational expenses (such as energy, maintenance, and repairs), and long-term quality, all of which impact residents' health and financial wellbeing. Life Cycle Costing (LCC) is a method that helps estimate the total costs over a home's lifespan, integrating both initial and ongoing expenses based on design choices that affect quality. However, using LCC in design stages might lead to a focus on reducing upfront costs, potentially overlooking investments in tangible features crucial for residents' long-term health and financial stability. This oversight could be attributed to inconsistencies in parameter selection for inclusion in an LCC model. For instance, due to budget constraints, housing providers might need to reduce upfront costs as construction expenses continue to rise. In such cases, photovoltaic panels, despite their long-term financial benefits for households, might be omitted to achieve immediate cost savings.

4.4. The complexity of the regulatory framework governing the sustainability of social housing

The challenge we face is simplifying the intricate regulations governing housing and sustainability. This complexity has made housing practitioners and developers uneasy, hindering their full acceptance of sustainable housing. This challenge stems from two main factors. Firstly, there's a need for clearer explanations of the fundamental principles and objectives behind sustainability regulations. Secondly, the complexity of these regulations often burdens local authorities responsible for enforcing and monitoring compliance in housing projects.

4.5. Meeting the diverse range of needs in multi-family housing within an affordable and sustainable framework through mass customisation strategies

Meeting the diverse range of needs in multi-family housing through mass customisation strategies is necessary to meet the varied requirements of numerous households within a sustainable and affordable framework. Industrialised methods of construction have the potential to leverage mass production techniques, optimise fabrication processes and reduce the environmental impact of construction through higher degrees of digitisation and a streamlined coordination. Unfortunately, the construction sector traditionally operates in silos. Architects, engineers, component makers, and construction companies working separately and with short-sighted strategies. Therefore, interdisciplinary collaboration is necessary to develop product platforms of standardised components, connections, and processes that can provide flexible and adaptable multi-family housing. Moreover, to deliver adaptable housing solutions for both short and long-term customization, it is crucial to consider Open Building principles that account for the lifespan of various building layers. Finally, integrating users into the customisation process through workshops and digital tools would result not only in the reduction of waste and efficient use of resources but as well in co-creating meaningful dwellings with a greater sense of ownership.

Table 2. Challenges focusing on the area "Design, Planning, Building" and related components of the transdisciplinary research framework

Challenges	Actors	Methods	Tools	Related Vocabulary	Related Case Studies
Integrating design for disassembly principles with industrialised construction practices to reduce the embodied carbon impacts of housing over the building lifecycle (ESR1)	Designers Housing providers Housing manufacturers	Case studies Exploratory interviews Life Cycle Analysis Observations Systematic literature review	Interviews guide Text analysis Surveys guide	Affordability Design for Disassembly Industrialised Construction	APROP | Temporary social housing for people at risk to residential exclusion Solar Decathlon Europe 2022
Lack of early integration of resident stakeholders in housing retrofit to yield benefits such as cost savings, reduced performance gaps, and increased social value (ESR2)	Academics Housing companies Municipalities Residents	Case Studies	Focus groups guide Text analysis	Community Empowerment Housing Retrofit Social Value Performance Gap in Retrofit	Community_Leeds HOUSEFUL: Els Mestres, Sabadell LILAC_Low Impact Living Affordable
The underutilisation of Life Cycle Costing (LCC) for households often leads to oversights in investing in tangible features that positively impact residents' health and financial wellbeing in the long term (ESR4)	Architects/designers Construction industry Cost consultants Health professionals Housing providers Resident community	Case study Interviews Knowledge co-creation Life cycle costing Participatory action research Taxonomy	Cost modelling Framework Text analysis Workshops	Community empowerment Energy poverty Housing affordability Life cycle costing Measuring housing affordability Social value	Dalamas Villa Pre-1919 Niddrie Road Retrofit Marmalade Lane

Challenges	Actors	Methods	Tools	Related Vocabulary	Related Case Studies
The complexity of the regulatory framework governing the sustainability of social housing (ESR5)	Environmental agencies Housing associations Housing authorities	Assessment systems Systems thinking Sustainability	Shared definitions Standardised protocols	Social Housing Sustainability of the Built Environment	Deben Fields (Garrison Lane) North Wingfield Road social housing complex.
Meeting the diverse range of needs in multi-family housing within an affordable and sustainable framework through mass customisation strategies (ESR14)	Architects Construction companies Manufacturers Residents	Case studies Semi-structured Interviews Workshop	Combined assessment tool Interviews guide Workshop guide	Affordability Industrialised Construction Mass Customisation	Diagoon Houses Patch22

4.6. Cross-cutting challenges

The convergence of research insights from the ESRs through their PhD abstracts, synthesized literature reviews, and identified key societal challenges suggests the interconnected roles of various fields, actors, and methods in shaping the future of affordable and sustainable housing. This underscores the need for a holistic and collaborative approach that transcends traditional disciplinary silos and academic boundaries.

The integration of design for disassembly with industrialized construction approaches is deemed crucial but currently lacks widespread understanding pointing to the need for the development of a comprehensive framework and guidelines for stakeholders, through a mixed-methods approach (qualitative and quantitative) as described by Davis. Furman emphasizes the importance of early integration of resident stakeholders to yield benefits such as cost savings, reduced performance gaps, and increased social value in housing retrofit. A mixed-methods strategy is employed, targeting both high-level retrofit stakeholders and residents through interviews and focus groups, respectively. Eighandour identifies the challenge of a potential oversight of tangible features crucial for households' health and financial wellbeing in the design of affordable housing due to the lack of a standardized process and the absence of a comprehensive framework when using Life Cycle Costing (LCC). Addressing this challenge is considered to be essential to prevent prioritizing construction cost reductions over quality, which could compromise dwelling performance and negatively impact health and financial wellbeing.

The challenge of simplifying complex regulations governing sustainable housing is described by Alsaeed, unveiling the importance of streamlining these regulations for broader acceptance, focusing on clarity in sustainability standards, resolving contradictions, and reducing the enforcement burden on local authorities. Martin points out the lack of integration and collaboration between multidisciplinary parameters and stakeholders in the construction industry, which hinders the effective implementation of mass customization in multi-family housing. A mixed-methods approach is employed, including a comparative case study analysis, the development of an integrated assessment tool, and workshops involving diverse stakeholders, aiming to achieve greater interdisciplinary knowledge integration and provide customized housing solutions.

Furman's investigation into European social housing disrepair aligns with Davis's focus on circular, social, and affordable housing. Both studies advocate for a paradigm shift away from conventional, top-down retrofit strategies towards more inclusive and participatory methodologies. Involving residents in the decision-making process, experts from fields such as sociology, architecture, urban planning, must collaborate with housing professionals to understand and integrate residents' perspectives effectively. This not only emphasizes the integration of diverse perspectives but also suggests the need for a dialogue and clear communication.

Furthermore, the design for disassembly and its integration with industrialized construction methods, investigated by Davis, demands a shift not only in design principles but also in communication channels between various stakeholders, including housing providers, designers, and manufacturers. Elghandour's work on the impact of housing conditions on health and the development of a Life Cycle Costing (LCC) framework shifts the concept of affordable and sustainable housing to encompass both health and long-term financial considerations, pointing towards a need for collaboration between healthcare professionals, architects, and financial experts.

Alsaeed's exploration of environmental sustainability and social housing challenges suggests that simplifying the complicated nature of regulations governing housing and sustainability is a

task that extends beyond a single discipline. Legal experts, policymakers, environmental scientists, and housing practitioners need to collaboratively streamline and clarify regulations. Aligning products and services with individual needs, as proposed by Martín's research on mass customisation in multifamily housing, calls for a convergence of expertise from architecture, construction, and users' experience domains.

The collective research efforts of the ESRs assert that the integration of diverse perspectives, taking into consideration the various factors encompassed (including among others, environmental impact, social inclusivity, health and wellbeing, and economic viability), is a requisite for addressing the intricate challenges posed in designing and building affordable and sustainable housing.

5. Interconnected challenges across three research areas

After identifying challenges derived from the research projects which interrelate projects within the area of “Design, Planning, Building”, the final step is to interrelate these challenges to others from the two areas, “Community Participation” and “Policy and Financing” (Table 3).

In the following subsections, we present potential relationships between the challenges focused on "Design, Planning, and Building" and challenges from the other two research areas (Tables 4-8). Additionally, we illustrate the connections between these challenges and other components of the transdisciplinary framework (see Deliverable 4.6), such as actors, methods, tools, vocabulary entries, case studies, and secondments. These relationships are visualized in a diagram and explained in a short text.

The diagrams have been created using a common graphic language and set of components to provide a detailed view of a complex problem. Beyond this, there is no mechanism underlying the generation of the diagrams other than the researchers' knowledge. Therefore, these representations convey a personal understanding of a multifaceted issue in a language that facilitates further dialogue and exchange with other researchers. In this regard, the knowledge encapsulated in the diagrams can be particularly meaningful for addressing specific real-world problems related to affordable and sustainable housing, involving the relevant actors (see Deliverable 4.7).

Table 3. Challenges in the three research areas

Design, Planning, Building	Community Participation	Policy and Financing
Integrating design for disassembly principles with industrialised construction practices to reduce the embodied carbon impacts of housing over the building lifecycle	Long-term engagement of actors in municipality-citizens collaboration towards sustainable neighbourhood development	Lack of political will
Lack of early integration of resident stakeholders in housing retrofit, which potentially yields benefits such as cost savings, reduced performance gaps, and increased social value	Reconciling the gap between housing studio education in architecture and real-world challenges in affordable and sustainable housing provision through a commons-based approach.	Breaking down the silos between disciplines and create supportive and effective housing for people with complex needs
The underutilisation of Life Cycle Costing (LCC) for households often leads to oversights in investing in tangible features that positively impact residents' health and financial wellbeing in the long term	Supporting community engagement in the development of community-lead initiatives	Lack of knowledge on targeted policy instruments to alleviate energy poverty
The complexity of the regulatory framework governing the sustainability of social housing	Limited understanding of the contribution of space in the success of urban common initiatives	Improving access to capital market for social housing organization green and social financing instrument
Meeting the diverse range of needs in multi-family housing within an affordable and sustainable framework through mass customisation strategies		Unlocking the full potential of the Social Value Act and analogue regulations in the housing sector

5.1. Integrating design for disassembly principles with industrialised construction practices to reduce the embodied carbon impacts of housing over the building lifecycle (ESR1)

Transitioning to the circular economy is high on the EU agenda and shows the potential to improve both environmental sustainability and affordability of housing in the long term. Industrialised construction integrated with design for disassembly presents potential to reduce the negative environmental impacts of construction over the whole life cycle by facilitating the systematic reuse of materials. There are however major challenges integrating these approaches in practice, which tend to be either political and financial in nature. Currently, a short-term view takes precedence; high upfront costs and uncertainty of what will happen to housing stock in the future present key financial barriers. This connects to a lack of legal protection of buildings from future destruction, rather than retention of either building parts or whole buildings. These challenges are exacerbated by unclear, and at times contradictory guidance on circular construction from the EU down to the local level. Furthermore, energy efficiency friendly policy can compromise the reduction of embodied energy over the whole building life cycle. Regarding community participation, it is important to have support from residents, otherwise housing providers may be disincentivised from applying innovative housing solutions. To overcome these challenges, built environment professionals and local councils require practical guidance based on input and consultation with stakeholders from different fields and exemplary case studies demonstrating successful implementation, ideally proving scalability. Interdisciplinary research, collecting information through interviews and surveys, and life cycle assessment are essential methods to further the circular economy transition in housing (Table 4, Figure 4).

Table 4. Possible links to challenges from other research areas

Design, Planning, Building	Community Participation	Policy and Financing
Integrating design for disassembly principles with industrialised construction practices to reduce the embodied carbon impacts of housing over the building lifecycle	Residents/end-users lack understanding of the processes and benefits of industrialised construction and design for disassembly, thereby inhibiting social acceptance and application of innovative solutions in housing	Circular construction is more expensive compared to conventional on-site construction as current policy and financial systems are not designed to reward the reuse of building materials
		Building materials are not legally protected from future destruction and demolition
		Guidance from the EU to local level on circular construction is unclear, at times contradictory, and lacks practical guidance and examples for implementation
		Energy efficiency friendly policy is at risk of increasing the embodied energy produced during the whole building life cycle

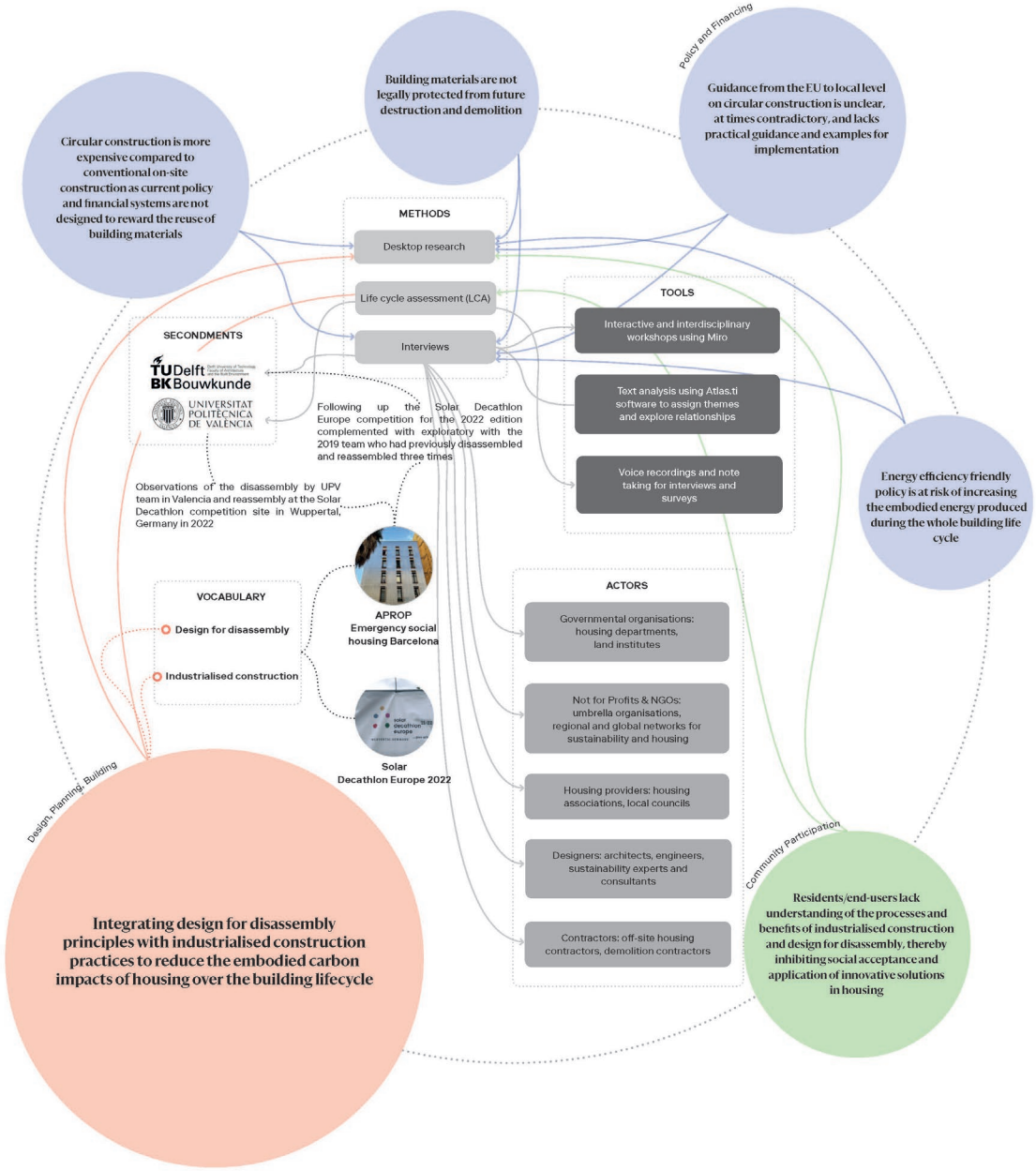

Figure 4. Connections between the challenge and other components of the transdisciplinary framework

5.2. Lack of early integration of resident stakeholders in housing retrofit, which potentially yields benefits such as cost savings, reduced performance gaps, and increased social value (ESR2)

Lack of early integration of social housing residents in retrofit decision-making can exacerbate fuel poverty, performance gaps, and resident disempowerment. Interviews with high-level stakeholders reveal the lack of political will to holistically address retrofit and energy performance, leading to market based technical solutions that de-prioritise the actual needs of residents. Rather, social housing, affordable housing, and sustainable housing are politically weaponised at the expense of equal access to quality housing. Supporting community engagement in retrofit can lead to long-term sustainable solutions. Collaboration between building owners and resident stakeholders in decision-making can repair fractious relationships, empower marginalised groups to engage with energy, increase social value, generate sustainable architecture, and reduce performance gaps. Focus groups and workshops.

offer a unique opportunity to collaborate between stakeholders and can facilitate valuable knowledge exchange. Researchers play a vital role in observing and analysing key themes to later apply to retrofit alongside architects and designers, translating information into design (Table 5, Figure 5).

Table 5. Possible links to challenges from other research areas

Design, Planning, Building	Community Participation	Policy and Financing
Lack of early integration of resident stakeholders in housing retrofit, which potentially yields benefits such as cost savings, reduced performance gaps, and increased social value	Supporting community engagement in the development of community-led housing initiatives	The lack of political will
	Long-term engagement of actors in municipality-citizens collaboration towards sustainable neighbourhood development	Energy poverty stems from various factors, including inadequate income, high energy prices, or substandard energy efficiency of dwellings. The challenge at hand involves alleviating energy poverty among disadvantaged households

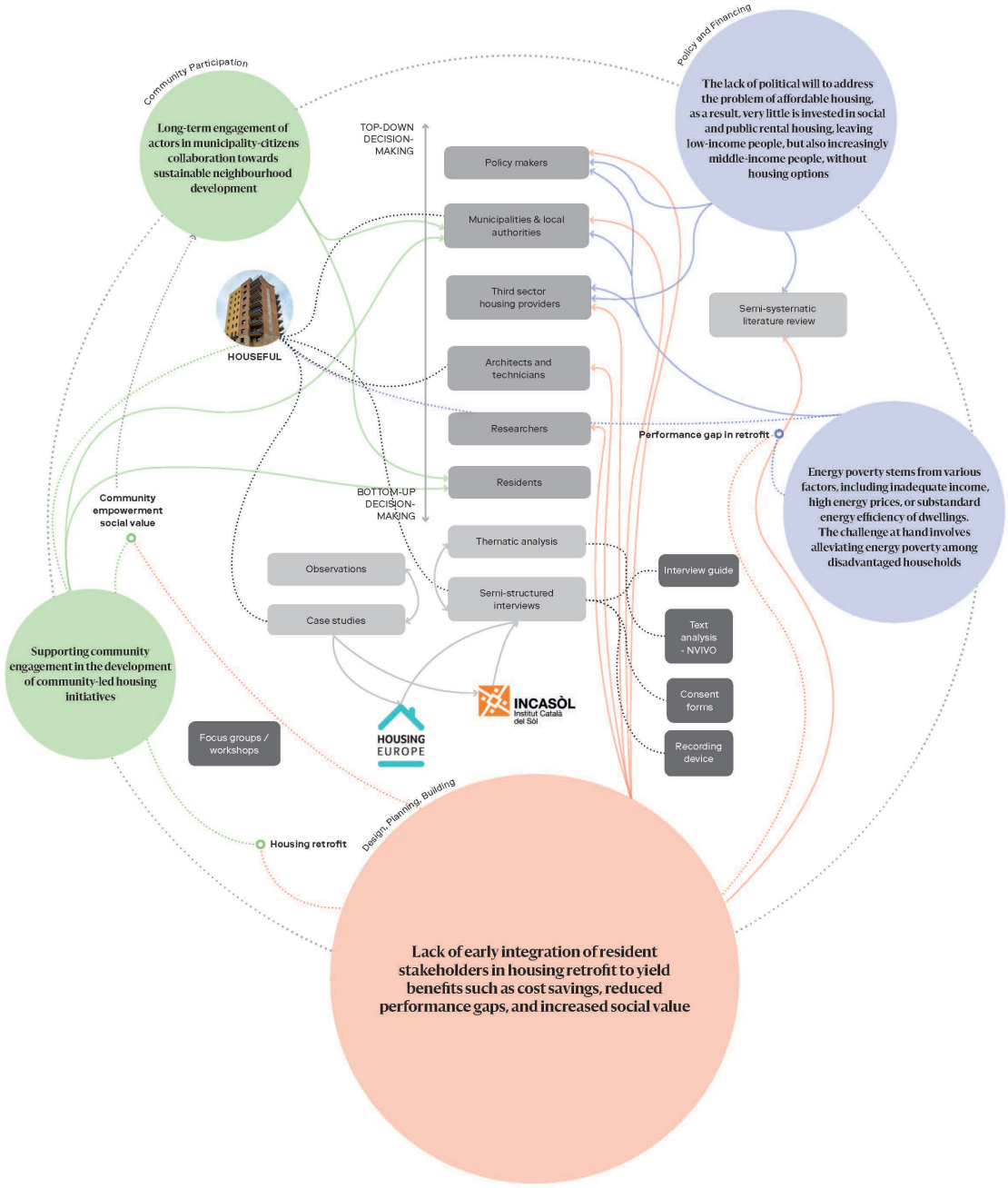

Figure 5. Connections between the challenge and other components of the transdisciplinary framework

5.3. The underutilisation of Life Cycle Costing (LCC) for household favours often leads to oversights in investing in tangible features that positively impact residents' health and financial wellbeing in the long term (ESR4)

Rethinking housing affordability involves considering both financial and health aspects. From the design stages, Life Cycle Costing (LCC) can support balancing construction costs, future operational expenses (energy, maintenance, repairs), and long-term quality affecting residents' health and financial wellbeing. However, the underutilisation of LCC for household favours often leads to oversights in investing in tangible features that impact residents' health and financial wellbeing in the long term. Financing, policy, and community efforts are essential to address this. A shift in the political will can promote investments in health-enhancing affordable housing. This investment helps mitigate energy poverty burdens, such as the Niddrie Road Retrofit case study. Increasing community awareness of long-term considerations of materials, ventilation, and energy systems can lead to choices benefiting climate and health. Such awareness can influence housing policies and stakeholders' agendas, encouraging the design and construction of quality affordable dwellings, unlocking the potential of regulations like the Social Value Act, and promoting household health and financial stability (Table 6, Figure 6).

Table 6. Possible links to challenges from other research areas

Design, Planning, Building	Community Participation	Policy and Financing
The underutilisation of Life Cycle Costing (LCC) for households often leads to oversights in investing in tangible features that positively impact residents' health and financial wellbeing in the long term	Supporting community engagement in the development of community-led housing initiatives.	Energy poverty stems from various factors, including inadequate income, high energy prices, or substandard energy efficiency of dwellings. The challenge at hand involves alleviating energy poverty among disadvantaged households
		The lack of political will
		Unlocking the full potential of the Social Value Act and analogue regulations in the housing sector

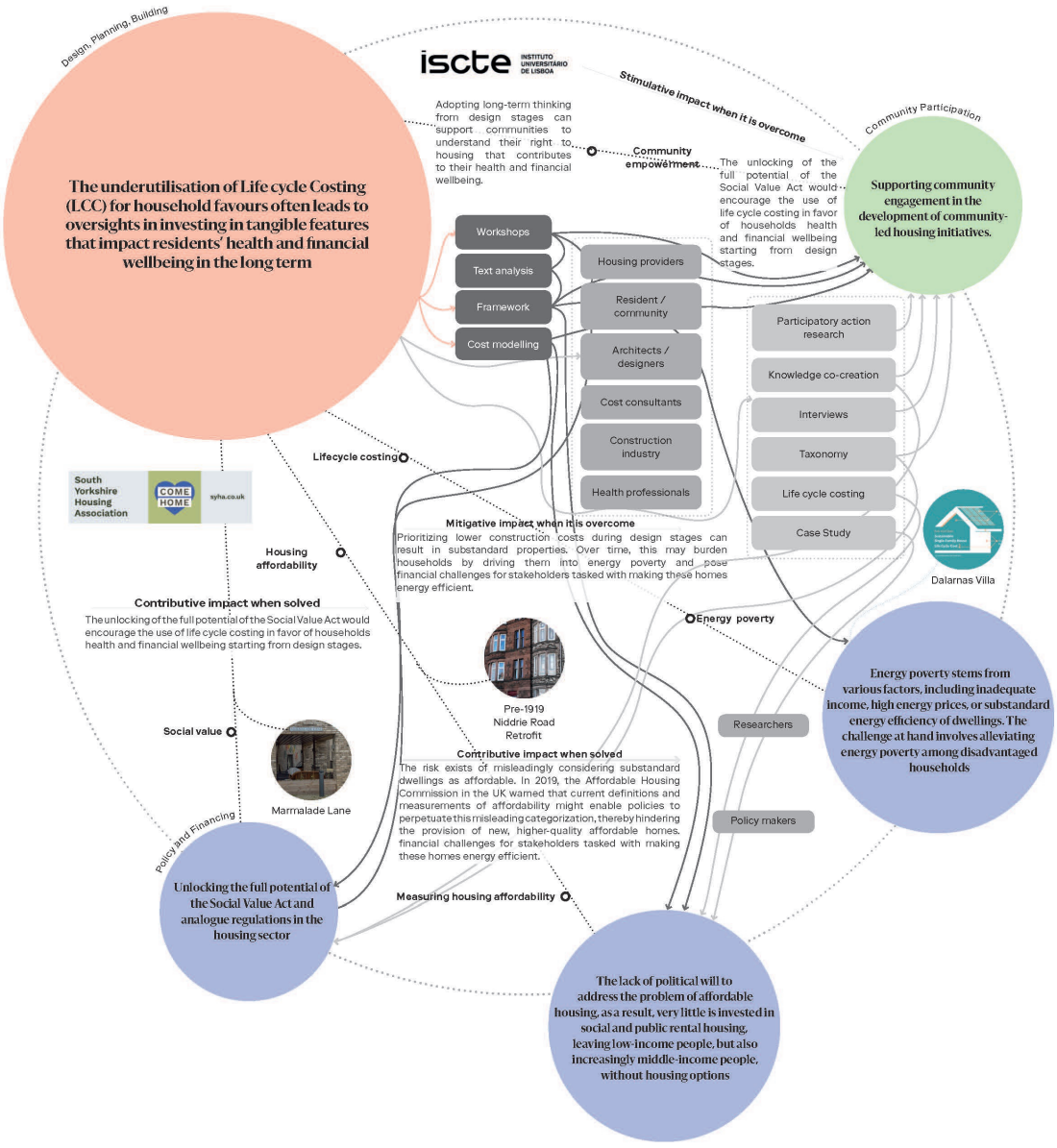

Figure 6. Connections between the challenge and other components of the transdisciplinary framework

5.4. The complexity of the regulatory framework governing sustainability of social housing (ESR5)

Across the three research areas of RE-DWELL, several challenges emerge that demand a thorough understanding of actor roles, along with appropriate tools and methods to overcome obstacles in developing socially and environmentally sustainable housing. Transdisciplinary approaches and collaboration are pivotal in tackling these challenges, closely intertwined with the intricate regulatory landscape. Particularly in policy and finance, overcoming the hurdle of political will is paramount, impacting authorities, local communities, and governments alike. Mapping these connections is central to the RE-DWELL objectives, which seek to establish a unified language and framework addressing both housing affordability and sustainability throughout Europe (Table 7, Figure 7).

Table 7. Possible links to challenges from other research areas

Design, Planning, Building	Community Participation	Policy and Financing
The complexity of the regulatory framework governing the sustainability of social housing	Long-term engagement of actors in municipality citizens collaboration towards sustainable neighbourhood development	The lack of political will
	Reconciling the gap between housing studio education in architecture and real-world challenges in affordable and sustainable housing provision through a commons-based approach	

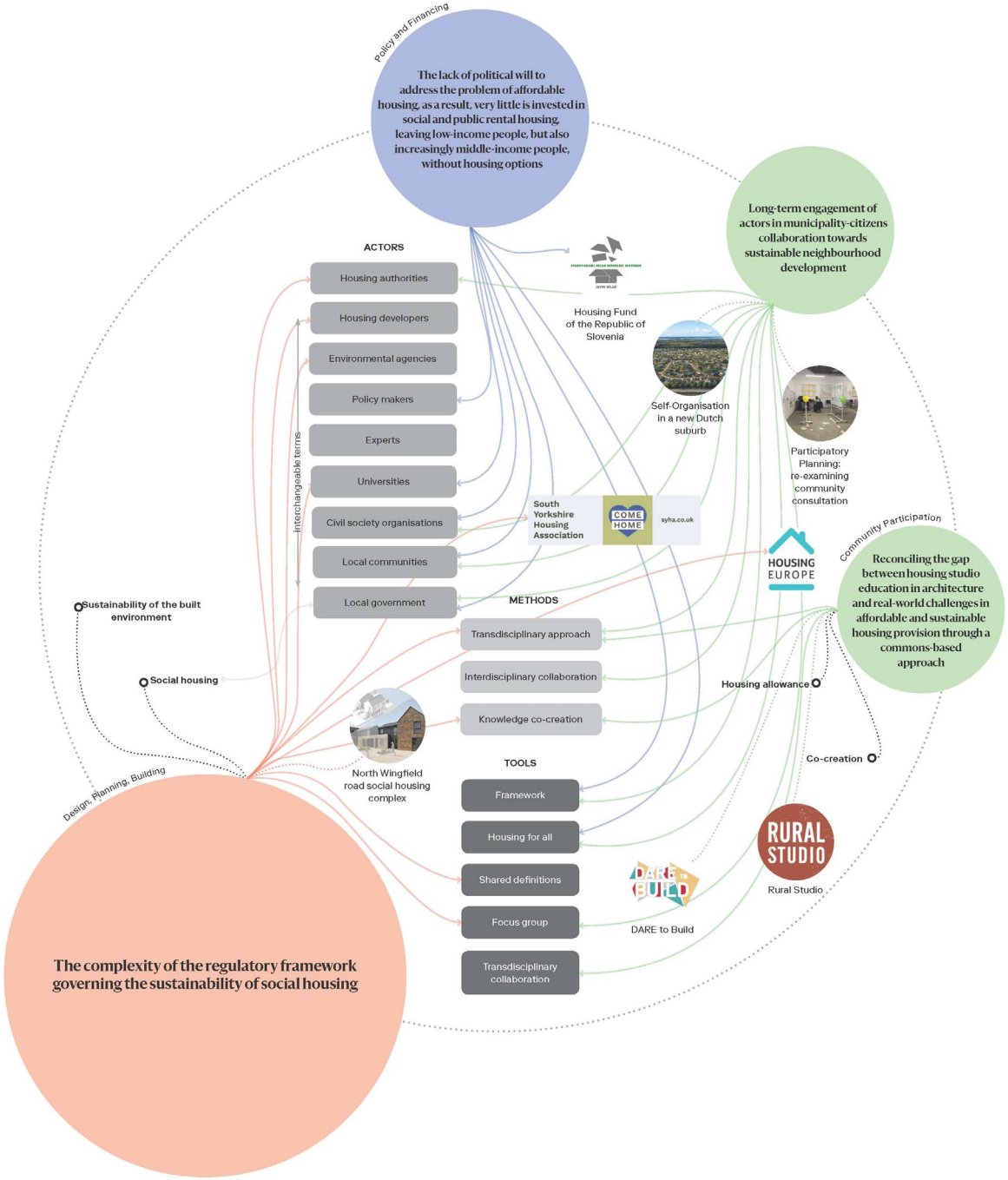

Figure 7. Connections between the challenge and other components of the transdisciplinary framework

5.5. Meeting the diverse range of needs in multi-family housing within an affordable and sustainable framework through mass customisation strategies (ESR14)

By promoting collaboration among housing authorities, architects and local communities, innovative and adaptable solutions to property rights and participation processes can be developed. These solutions empower communities by involving them in decision-making, fostering knowledge co-creation through stakeholder workshops to break down the silos between disciplines barriers and devise integrated solutions. Similarly, interdisciplinary collaboration among construction companies, building component suppliers, engineers, architects, and researchers would foster manufacturing partnerships, standardised components and processes, a deeper understanding of design for disassembly principles, and ultimately the development of a product platform based on industrialised components, streamlining the delivery of flexible and resilient multi-family housing (Table 8, Figure 8).

Table 8. Possible links to challenges from other research areas

Design, Planning, Building	Community Participation	Policy and Financing
Meeting the diverse range of needs in multi-family housing within an affordable and sustainable framework through mass customisation strategies	Supporting community engagement in the development of community-lead initiatives	The current housing markets fail to adequately address the diverse housing needs of the population
Integrating design for disassembly principles with industrialised construction practices to reduce the embodied carbon impacts of housing over the building lifecycle		

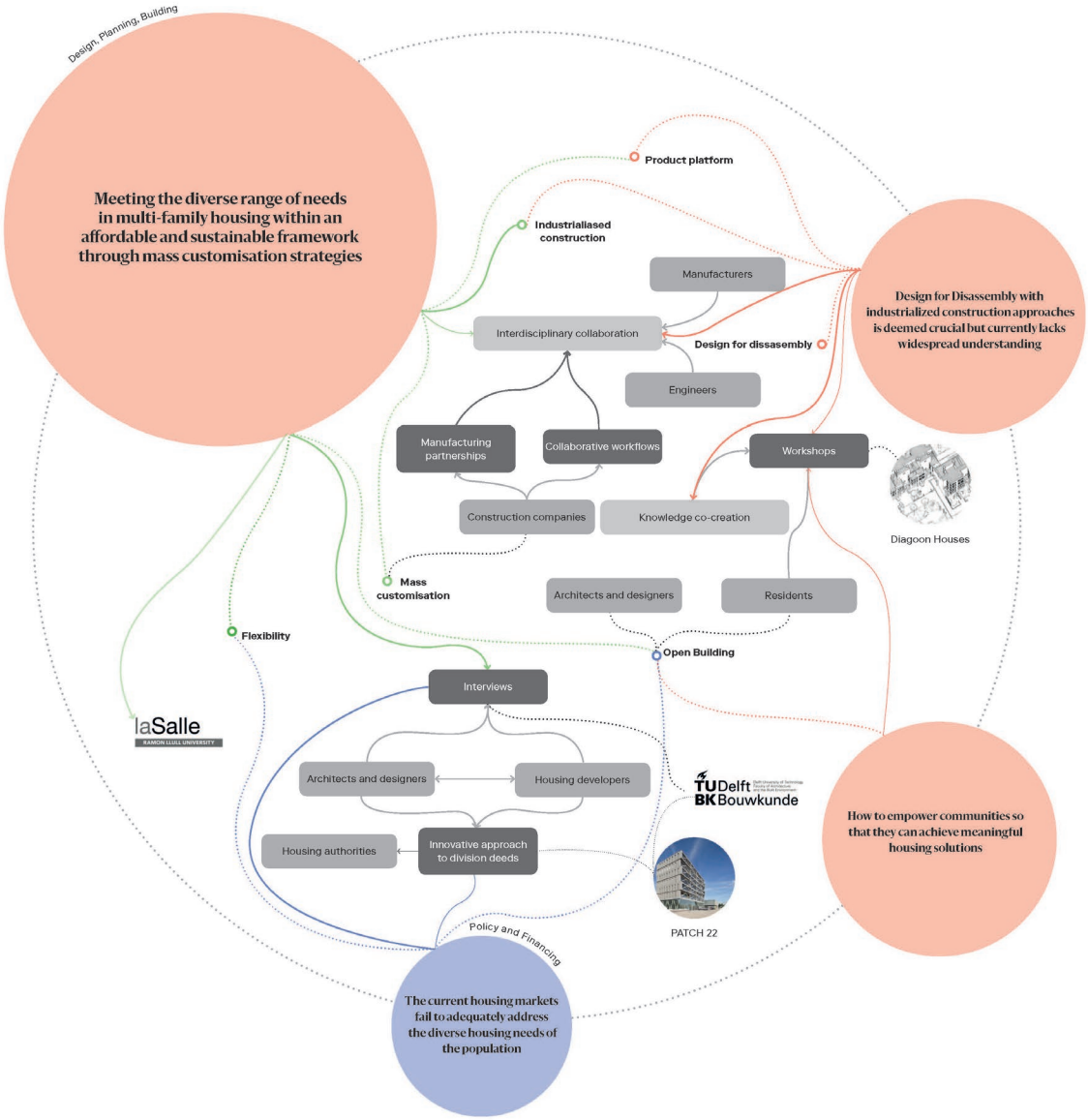

Figure 8. Connections between the challenge and other components of the transdisciplinary framework

6. Directions for future research

From the collaborative research addressing the topic “Design, Planning, Building” within a transdisciplinary perspective, several cross-cutting issues arise that can be relevant for future research to be conducted by early-stage researchers within their PhD theses, as well as for real-world activities aimed at providing affordable and sustainable housing:

Early Stakeholder Engagement: Involving residents early in the housing design and construction process is pivotal to ensuring that the outcomes meet the actual needs and preferences of the end-users. Traditional top-down approaches often overlook the practical insights and lived experiences of residents, leading to housing solutions that may not align with their daily living patterns or specific needs. By engaging residents from the outset, it is possible to address:

- **Improved Solutions:** Housing solutions become more tailored and effective, addressing both functionality and social value. Residents’ input can help identify practical issues that might be overlooked by technical experts, thereby improving overall performance and usability.
- **Enhanced Social Value:** Involving residents fosters a sense of ownership and empowerment, contributing to improved well-being and quality of life. This participatory approach ensures that housing solutions do not merely impose designs but co-create them with the community, leading to greater satisfaction and acceptance.
- **Cost Savings:** Early integration of residents can identify cost-effective solutions that are practical and implementable, potentially reducing unnecessary expenses and improving the overall economic efficiency of the project.

Interdisciplinary Collaboration: Breaking down silos in the construction sector is essential for optimizing processes and reducing environmental impacts. The construction industry often operates in a fragmented manner, with architects, engineers, and builders working independently rather than collaboratively. Interdisciplinary collaboration can:

- **Optimize Processes:** By fostering collaboration among different disciplines, it is possible to streamline construction processes, enhance coordination, and improve efficiency. This can lead to higher quality outputs and reduced project timelines.
- **Reduce Environmental Impacts:** Collaborative efforts can better integrate sustainable practices such as industrialized construction and design for disassembly. This holistic approach ensures that environmental considerations are embedded throughout the project lifecycle, from design to deconstruction.

Policy and Financial Alignment: Addressing political and financial barriers is critical for the widespread adoption of sustainable practices. The transition to practices like the circular economy and health-enhancing affordable housing often faces resistance due to high upfront costs and uncertain long-term benefits. To overcome these barriers:

- **Policy Support:** Governments and policymakers need to create favourable conditions for sustainable practices through incentives, subsidies, and supportive regulations. This could include tax breaks for sustainable construction, grants for housing projects, and clear guidelines on circular economy practices.
- **Financial Models:** Developing innovative financing models that spread the cost over the lifecycle of the building can make sustainable practices more economically viable. Life Cycle Costing (LCC) is a tool that can help balance initial investment with long-term savings, making a strong case for sustainable investments.

Community and Policy Support: Raising awareness and engaging the community is essential to drive demand for sustainable housing solutions. Community support can significantly influence policy and funding decisions, as well-informed residents are more likely to advocate for and adopt sustainable practices. Key actions include:

- **Educational Campaigns:** Informing the community about the benefits of sustainable housing, such as improved health outcomes and reduced energy costs, can build support and demand for such initiatives.
- **Policy Influence:** Engaged and informed communities can put pressure on policymakers to prioritize sustainable housing projects. This bottom-up approach ensures that policies reflect the needs and desires of the population.

Regulatory Navigation: Developing shared vocabularies and coherent frameworks is necessary to help stakeholders navigate the complex regulatory environment associated with sustainable housing projects. A clear and consistent regulatory framework can:

- **Promote Compliance:** Simplifying regulations and creating clear guidelines can make it easier for developers and housing practitioners to comply with sustainability standards. This reduces the administrative burden and promotes higher uptake of sustainable practices.
- **Facilitate Collaboration:** A common language and set of definitions can enhance communication and collaboration among stakeholders, including housing associations, local authorities, and environmental agencies. This unified approach ensures that everyone is working towards the same goals with a clear understanding of requirements and expectations.

By integrating these transversal themes, housing projects can become more effective, sustainable, and socially inclusive. Early stakeholder engagement ensures that solutions are user-centred and practical, while interdisciplinary collaboration optimizes processes and environmental outcomes. Policy and financial alignment make sustainable practices more viable, and community support drives demand and policy change. Clear regulatory frameworks facilitate compliance and collaboration, creating an ecosystem where sustainable housing can thrive.