GREENER FUTURES PARTNERSHIP

Social housing retrofits for the future

A state of the art of the socio-technical landscape for low-carbon innovation partnerships

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Picture credits (cover page)

Top left: Erneley Close EnerPHit retrofit, One Manchester. Credit: Eastlands Homes (now One Manchester). [https://www.greenbuildingstore.co.uk/erneley-close-enerphit-mvhr-triple-glazed-timber-windows/#prettyPhoto[album-1]/9/]

Top right: Energiesprong pilots (Clifton flats) in Sneinton, Nottingham City Homes. Credit: Energiesprong UK.[https://www.energiesprong.uk/projects/nottingham]

Bottom: Agar Grove estate redevelopment, Camden City Council. Credit: Mae. [https://www.mae.co.uk/projects/agar-grove-estate]

Executive summary

"The scale of the net zero challenge is immense, but not beyond our reach. However, it is going to take a truly collaborative effort if we are to achieve our aims.

Mark Henderson, chief executive of Home Group

Collaboration is at the core of innovation. As the social housing sector aims for low-carbon futures, multiple innovation pathways come into focus. The state-of-the-art about the current low-carbon transition indicates the need for greater maturity and consistency across both policy and industry. Toward this end, the Greener Futures Partnership's 'Five Point Plan' provides the basis for a systemic approach to innovation in energy-efficient social housing retrofits.

The report reviews the state of the art in energy-efficient retrofits in social housing. It investigates the multiple socio-technical factors that influence the design, adoption and evaluation of different retrofit measures, including innovative partnership arrangements that can further these in the future.

Collaboration and partnerships

Which multi-organisational partnership arrangements currently exist that can deliver retrofits in innovative ways?

- Social housing retrofit demonstrator programmes typically rely on cross-sectoral partnerships around a well-defined, shared value proposition.
- Partnerships can comprise one or several housing providers, local authorities, architects, structural engineers and/or main contractors, expert consultants, energy service companies (ESCOs), researchers and/or experts at innovation agencies – each providing a specific role, expertise and leverage at different stages of the retrofit process.
- Partnerships target specific forms of innovative energy-efficient housing retrofits, but may also be embedded in wider urban regeneration programmes that deliver complementary solutions for urban sustainability.
- The success of demonstrator programmes relies on various retrofit coordination roles, which may be filled by one or several actors. These primarily consist of: 1) *project activation and marketing* to engage stakeholders, catalyse s funding, and integrate local value/supply chains; and 2) *retrofit coordination* properly said, ensuring project oversight, scheduling and collaboration across all involved parties.

Approaches to retrofit

What are the relative advantages and challenges of deep vs. step-by-step approaches to retrofits in social housing?

The most rational and cost-efficient way to retrofit is the 'fabric-first' approach, adopting the following steps:

1. Fabric improvements to improve thermal performance, mainly through insulation, as well as window and door replacements
2. Optimising thermal flows with mechanical ventilation and well-designed heating system
3. Installing renewable energy sources on-site or connecting to a local supply
4. Contracting green energy supply, and offsetting any remaining carbon, if renewable energy cannot be produced on-site, or if technical difficulties hinder energy-efficient interventions

The most common approach to retrofits is a deep, whole-house approach. However, this requires higher capital investment with longer ROIs that might take too long to recover for housing associations.

Step-by-step whole house approaches seem less common but can be integrated more easily in existing financial plans, although some interventions may require future upgrades to meet net zero carbon targets.

Housing retrofits are most coherent when part of wider regeneration and smart district refurbishment programmes that leverage district and/or community energy production, smart and active mobility, collaborative governance, and cross-sectoral collaboration as part of Public-Private-People (4P) partnerships.

Technology & Equipment

Which are the main technologies available in terms of fabric, renewable energy and monitoring of energy consumption and indoor environmental quality?

Commonly used technologies and equipment across demonstrator programmes include:

- *Monitoring equipment*: ample monitoring of existing energy use, simulation of predicted savings, and monitoring of post-retrofit energy use. Monitoring equipment include various types of sensors and data loggers, thermal imaging cameras, drones, and 3D laser scanners, among others.
- *Fabric improvements*: mainly external wall insulation (EWI) as well as floor and roof insulation. Cavity wall insulation applies to a small range of reviewed properties, and interior wall insulation (IWI) mainly concerns listed buildings or areas with specific design codes.
- *Collaboration, visualisation and project management:* Building Information Modelling (BIM), Digital Twins, and even 3D city models can help manage both retrofit projects and post-retrofit property management. The 3D visualisation capabilities of BIM and 3D city models can enhance and simplify communication among project partners, depending on the needs and scale of the projects.

Data & monitoring

How can social housing contribute to achieving net zero carbon targets in the built environment? How can social housing retrofits resolve performance gaps?

- Sufficient data collection should be conducted before, during and after retrofit works. This includes temperature levels, indoor air quality, live energy meter readings as well as occupant behaviour and preferences in terms of thermal comfort and energy use.
- High quality data helps to assess, design, simulate, monitor and evaluate thermal performance and energy use throughout the retrofit process, and help identify the preferred retrofit options and related technologies.
- Monitoring should be continuous, make use of post-occupancy evaluations, and involve customers/occupants consistently from scoping to in occupation assessments.
- An understanding and appreciation of customer experiences, habits, and satisfaction are essential for thermal comfort, well-being, sustainable lifestyles, as well as the overall environmental performance of the property (including thermal and energy performance).
- University partners can play a key role in providing support for extensive data collection, monitoring, and analysis, including technical data and customer experiences.

Customer engagement

What are the most effective ways to engage tenants/residents in social housing retrofits? What are the opportunities in terms of community building and fostering sustainable lifestyles?

- Best practice in customer engagement comprises effective communication and customer involvement throughout the life cycle of retrofit projects, for example using a co-creation or co-production approach that will help minimise performance gaps and support customer 'ownership'
- Key input from customers includes understanding energy consumption behaviour, helping to shape design briefs, post-occupancy evaluation (POE), participatory monitoring and leading community-wide initiatives.
- Customers are best considered as stakeholders and partners who are central to delivering energy-efficient retrofits, social value and community well-being.
- Retrofit liaison officers are particularly important in coordinating communication and engagement between contractors and residents, including for effective scheduling and management of technical difficulties.

Legal

Which are the main legal considerations for retrofit innovation? How can cross-tenure retrofit programmes be delivered most effectively?

- In a UK context, retrofits that involve mixed tenure must carefully assess leaseholders' reasonable contribution in the form of maintenance costs rather than investment in property improvements (see the contentious retrofit process for five tower blocks at Oxford City Council 2016-2017). Leaseholders are unlikely to contribute to the costs of retrofit measures beyond building maintenance and repair costs that would typically be mentioned in their leases.
- Mixed tenure therefore calls for careful planning and bespoke engagement with leaseholders, as well as complex funding streams. Failing to engage leaseholders appropriately can particularly damage trust relations with housing providers.
- Additional legal considerations may include data privacy for continuous monitoring purposes, and access to property issues during retrofit works. Effective customer engagement is key there also.

Jobs, skills and Training

What are the opportunities in terms of job creation and skills?

- Appropriate skills and training are the linchpin of both individual and mass-retrofits.
- Currently, there is a massive skills and labour shortage that severely limits market maturity and the capacity to deliver high-quality, affordable housing retrofits.
- Demonstrator programmes and mass retrofits in social housing will create strong demand and opportunities for upskilling in terms of construction workmanship and retrofit coordination.
- Due to their community focus and their employment and training schemes, housing associations can actively contribute to skills development and job creation.
- Emerging schemes such as the London mayor's £10 billion Innovation Partnership will help strengthen training and integrate local and regional value chains. BEIS' 'Ten Point Plan for a Green Industrial Revolution' should also leverage green construction jobs and skills at scale.

Finance, business model and market integration

Which business models exist at present that can deliver retrofits in innovative ways?

- Emerging opportunities include combining grant funding, traditional loans, and more complex financial instruments that help de-risk capital investment and ensure long-term systemic value.
- Green finance, underpinned by consistent ESG reporting, can help create economies of scale and market maturity that will in turn benefit the wider housing sector as well as cross-sectoral urban and district regeneration.

- Business model innovation presupposes the use of ‘one-stop-shops': they simplify customer journey for landlords by integrating local value chains and securing relevant funding schemes.
- Project activator and coordination roles are essential. They are often conducted by intermediary organisations such as one-stop-shops or in-house by highly skilled and motivated PAS 2035-certified retrofit coordinators.
- The collaborative, partnership model to retrofit portfolio innovation (e.g. through 4P partnerships) is central to delivering both individual retrofit schemes and wider urban retrofits.

Contents

Glossary & abbreviations

The following glossary provides brief definitions and/or descriptions of the key terms, and acronyms and abbreviations used in the report. Because the report is interdisciplinary, the terms used in the glossary may have different meanings across the AECOM industry (i.e. Architecture, Engineering, Construction, Operations, and Maintenance), local government stakeholders and housing associations.

GLOSSARY	
Adaptive thermal comfort	Occupants' experience of thermal comfort which may change over time or according to building condition (e.g. after retrofit)
AECOM industry	Architecture, Engineering and Construction, Operations & facilities Management industry
ASHP	Air source heat pumps
BEIS	Department for Business, Energy and Industrial Strategy
BIM	Building information Modelling
BM	Business model
CIH	Construction Innovation Hub
CIH	Chartered Institute of Housing professionals
Community heating / energy	Heating/energy produced in close proximity to homes, at a lower scale than district heating, often developed by housing providers and/or community groups
CWI	Cavity wall insulation
Decent Homes	Relates to the standard definition of what constitutes 'Decent Homes' (DCLG, 2006), now under new stakeholder consultation
Design codes	Local design policies meant to foster high quality design in the built environment
District heating	Generation of (low-carbon) heat at urban district level, typically led and/or developed by local authorities
Energiesprong	Deep, whole-house retrofit methodology and business model initially piloted in the Netherlands by the Dutch government. Literally: 'energy leap'.
EnerPHit	Retrofit standard to nearly Passivhaus standard, typically combining fabric first approach, high indoor environment quality and renewable energy generation
ESG reporting	Environmental, Social and Governance reporting
EWI	External Wall Insulation
Fabric first approach	Improve the energy efficiency of the building fabric/envelope before installing renewable energy or other measures
Fuel poverty	Denotes households' inability to pay for energy bills. Typically approaches as 'high need – high costs'
HVAC	Heating, ventilation and air conditioning
GHG – LAD	Green Homes Grant – Local Authorities Delivery: Separate from the Green Homes Grant voucher scheme for private homeowners

GSHP	Ground source heat pump
HA	Housing association
HACT	Housing Association's Charitable Trust
HVAC	Heating, ventilation and air conditioning
IWI	Internal Wall Insulation, usually adopted in listed buildings or in buildings located in conservation areas
LA	Local authority
LA 21	United Nationals Local Agenda 21 framework developed at the UN Rio Conference (1992) and reiterated in Johannesburg (2002)
LPA	Local planning authority
MHCLG (formerly DCLG)	Department for Housing, Communities and Local Government
MMC	Modern Methods of Construction. Also: offsite / prefabrication of construction components
MVAC	Mechanical ventilation and air conditioning. In retrofits, typically refers to mechanical ventilation systems with heat recovery.
Nearly zero carbon	Denotes development and retrofits that achieve low carbon emissions in both construction and operational energy, based on a whole life cycle perspective
Net zero carbon	Net zero carbon emissions achieved through new development and retrofits, accounting for both construction and operational energy through a whole life cycle perspective: UKGBC (2019) Standard Framework Definition
NPPF	National Planning Policy Framework, amended 2019
PAS 2030	Workmanship excellence framework to deliver energy-efficient retrofits, in conjunction with PAS 2035
PAS 2035	Framework for excellence in energy-efficient housing retrofits
Performance gap	The difference between EPC-based estimations of energy savings and real/observed energy consumption patterns
PPP	Public-Private Partnership
4P	Public-Private-People Partnership
PV	Photovoltaic panels for electricity microgeneration, typically w/ battery storage
RdSAP	Reduced data Standard Assessment Procedure
Rebound effect	Situation where occupants begin consuming more energy as they are now able to enjoy thermal comfort thanks to improved thermal performance post-retrofit. This influences actual energy savings.
RIBA	Royal Institute of British Architects
RIBA Plan of Work (2020)	Standard process for the full life cycle of development projects in the built environment by the Royal Institute of British Architects
SAP	Standard Assessment Process

Solar collectors	Solar panels with thermal storage for warm water and/or heating
SDGs	The Sustainable Development Goals that comprise the United Nations 2030 Agenda on Sustainable Development
SHDF	Social Housing Decarbonisation Fund
SROI	Social return on investment
SWI	Solid wall insulation (either external or interior)
Thermal comfort	Occupants' feeling of being warm or cold. When stated positively, it means occupants feel comfortably warm in their home.
UKGBC	UK Green Building Council

Introduction and research aims

The introduction sets the general context for energy-efficient retrofits in social housing. It concludes with a presentation of the research aims for the report.

Collaboration for innovation

Collaboration is at the core of innovation. As the social housing sector aims for low-carbon futures, multiple innovation pathways come into focus. The state-of-the-art about the current low-carbon transition indicates the need for greater maturity and consistency across both policy and industry. Toward this end, the Greener Futures Partnership's 'Five Point Plan' provides the basis for a systemic approach to innovation in energy-efficient social housing retrofits.

The GFP's work is most timely, in consideration of recent industry and policy targets, guidance and recommendations. The recent publication of the National Retrofit Strategy consultative report by the Construction Leadership Council highlights the importance of the partnership model to delivering housing retrofits at scale (CLC, 2021). Likewise, the state of the art around business models and value-generation for housing retrofit innovation indicates cross-sectoral collaboration is essential to structure local value chains and enable a portfolio of innovative projects. For instance, Homes provided by local councils and housing associations account for 17% of the total UK housing stock, equating to 4.5m homes.[1] Social housing can be regarded as a test ground to develop and upscale retrofit solutions that will then be adapted across the rest of the UK housing stock (IET & Nottingham Trent University, 2020). The Climate Change Committee (2019, p. 36) highlighted that "social landlords can be well-placed to oversee mitigation and adaption action", for example through their community focus, coordinated stock upgrades.[2] Due to their strong community focus, registered social housing providers have a comparatively unique opportunity to leverage social value and innovation at scale. Based on interviews and workshops with social landlords in Greater Manchester, Cauvain and Karvonen (2018) suggest social housing providers can leverage *sectoral*, *social*, *process* and *civic* innovation simultaneously, positioning them as prime innovators. There are also signs of a growing alignment between financial institutions (such as banks and pension funds) and social and affordable housing providers in terms of social value, net zero carbon targets, targeted environmental quality, and wider community benefits (see Green Finance Institute, 2020; The Good Economy, 2020). There is also recent evidence of government funding that is more effectively crafted, alongside timely, expert guidance and recommendations from leading professional bodies across the construction, architecture, planning and property sectors. Finally, recently policy and industry orientations concerning the town planning system point to upcoming evolutions in local plan-making, development management and building control that will enable greater environmental quality, community benefits and net zero carbon performance, not least of which through the adoption of PlanTech, local climate action plans and design codes.

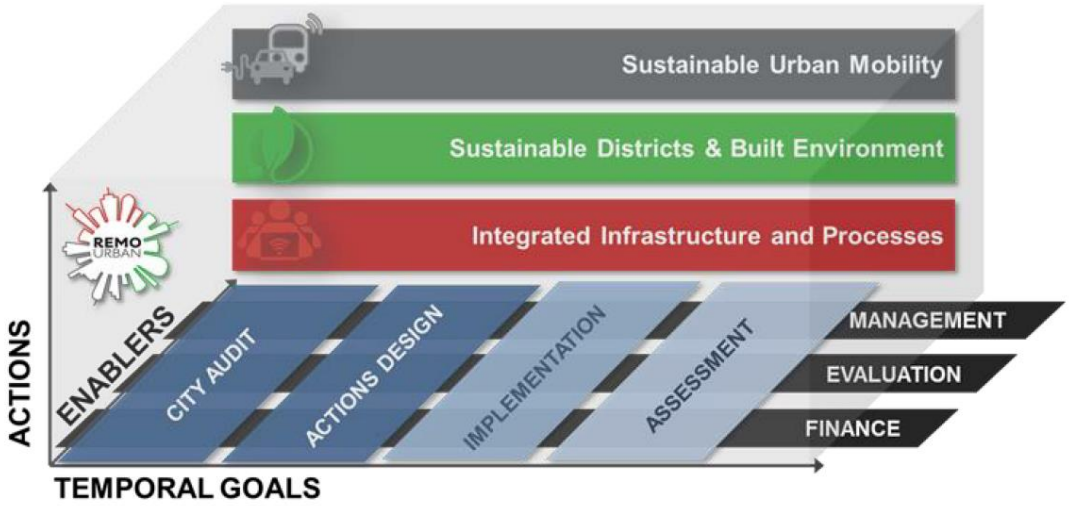
Altogether, these create exciting opportunities to collaboratively design, test and upscale a portfolio of innovative retrofit options and technologies across different property types, household needs, and tenure. At the core of this bold endeavour is the opportunity to partner with end-users (i.e. customers/occupants) to collaboratively design, roll out and evaluate energy-efficient property retrofits that are more fit-for-purpose and capable of filling performance gaps. This report demonstrates performance gaps are threefold and interconnected. These are: 1) *measurement-related performance gaps* in terms of discrepancies between EPC-based estimated energy savings and actual energy savings based on real energy consumption data; 2) *thermal gaps* arising from inadequate technical skills and craftmanship among building trades to ensure thorough airtightness and thermal performance across a building's fabric; and 3) *behaviour gaps* arising from inadequate occupant engagement over the course of retrofit projects, leading to inappropriate use of innovative

[1] Based on the 2011 census baseline.

[2] See the Climate Change Committee's policy recommendations in the 'UK housing: Fit for the Future?' report: [https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/]

technologies, and the adoption of retrofit technologies that are not user-friendly. One can also mention the lack of appropriate retrofit coordination and collaboration across all parties involved (including scheduling of contractors' interventions). This is further exacerbated by a lack of integrated value/supply chains and a legacy of inconsistent government funding which has generated uncertainty across the sector. Thankfully, the last ten years have also witnessed innovative demonstrator programmes across the UK and Europe that shed light on a range of promising options for further experimentation and upscaling led by social housing partnerships. As sector-wide and cross-sectoral partnerships pave the way to upscaled portfolio innovation, there are also opportunities for joining up investment in social and affordable housing retrofits with wider urban regeneration and energy infrastructure renewal to leverage energy-efficient, inclusive urban retrofits at city-regional scale (Eames et al., 2014; Hodson & Marvin, 2017), and for local councils to act as enablers through building controls and more flexible plans (Häkkinen, Ala-Juusela, Mäkeläinen, & Jung, 2019; Häkkinen, Rekola, Ala-Juusela, & Ruuska, 2016). Toward this end, Public-Private-People (4P) partnerships provide a promising avenue to decarbonise housing development and retrofits at scale, including through local development planning and smart city strategies (Huston, Rahimzad, & Parsa, 2015; Kuronen, Junnila, Majamaa, & Niiranen, 2010; T. Liu, Mostafa, Mohamed, & Nguyen, 2021). A noteworthy demonstrator programme is the EU Horizon 2020 REMOURBAN project, featuring three lighthouse cities, including Nottingham, where the programme was deployed in the Sneinton area, and was also part-funded by ECO. The approach aims at district-wide urban regeneration by focusing on housing retrofits, district heating, sustainable mobility and transport (including small vehicle fleets for last mile delivery of goods), and use of smart technology. The comprehensive urban retrofit model is also underpinned by enhanced cross-stakeholder collaboration and a management framework, comprising: local authorities positioned as project 'enabler'; universities providing R&D and technical support; continuous monitoring; programme evaluation; and complex finance (García-Fuentes & de Torre, 2017). Below is a diagram that encapsulates the REMOURBAN model by García-Fuentes and de Torre (2017, p. 330):

Figure 1 - The REMOURBAN model to urban district retrofits (García-Fuentes & de Torre, 2017, p. 330)



The benefits of social housing retrofits

Many reports and journal articles review the benefits of social housing retrofits. These can be real (i.e. measured based on actual data and monitoring) or expected as objectives for the retrofit projects. The identified benefits also overlap with and strengthen each other. These include, among others:

Thermal performance and occupant/community wellbeing

- Thermal comfort for occupants

- Reductions in energy consumption, and reductions in energy bills for occupants
- Decarbonisation of the housing stock, in observance of national policy and organisational targets
- Fuel poverty alleviation
- Treating damp and mould to improve a building's environmental quality and prevent related health problems
- Wider community benefits in terms of public health, community identity and well-being, property values, and even life chances (e.g. when combined with training and employment schemes)
- Customer satisfaction and well-being
- Promotion and fostering of sustainable lifestyles

Sustainable construction and operations

- Reduction in water consumption
- Use of on-site renewable energy: solar PV, thermal solar collectors, biomass, district heating, air source heat pumps, ground source heat pumps (as community or district heating), OR procurement of green energy from energy suppliers
- Use of smart technologies: e.g. smart sensors, drones for site surveys, smart meters, Building Information (Modelling) and Digital Twins, robots for hard-to-access floor insulation
- Use of Modern Methods of Construction (i.e. prefabricated modular components) and related efficiencies in terms of lean construction and on-site construction management
- Carbon storage: particularly through the use of hemp and straw, if used at scale
- Use of low-carbon and biogenic/bio-based construction materials

Collaboration

- Requires and augments collaboration among professionals in the sector, and between public and private actors as well as customers

Sustainable investment and climate resilience

- Investment in future proof homes now to mitigate future costs of climate change and environmental damage
- Intensification of net zero and nearly zero retrofit demonstrators now to build market maturity and roll out mass retrofits at pace
- Job creation and upskilling

Unsurprisingly, these aforementioned benefits largely overlap with the objectives of the GFP demonstrator projects. This indicates general alignment both across the UK and internationally regarding the urgency and overall added-value of investing in comprehensive energy-efficiency interventions in a collaborative way.

Additional, long-term and indirect benefits include helping to structure local value chains (i.e. integrated supply chains that deliver combined added-value). Indeed, the scale of the challenge for nation-wide housing retrofits is compounded by the lack of a structured retrofit market, a shortage of skilled labour among building contractors, and a related shortage of retrofit project coordinators. As pioneer programmes within the wider housing sector, social housing retrofits can therefore help deliver economies of scale, greater market maturity and alleviate fuel poverty among the most-needy households and lowest performing properties. Finally, cumulative experience and knowledge sharing across the sector will enable collective capacity building among housing providers, national government, local authorities, contractors, material and building suppliers, designers, researchers, private investors, and residents.

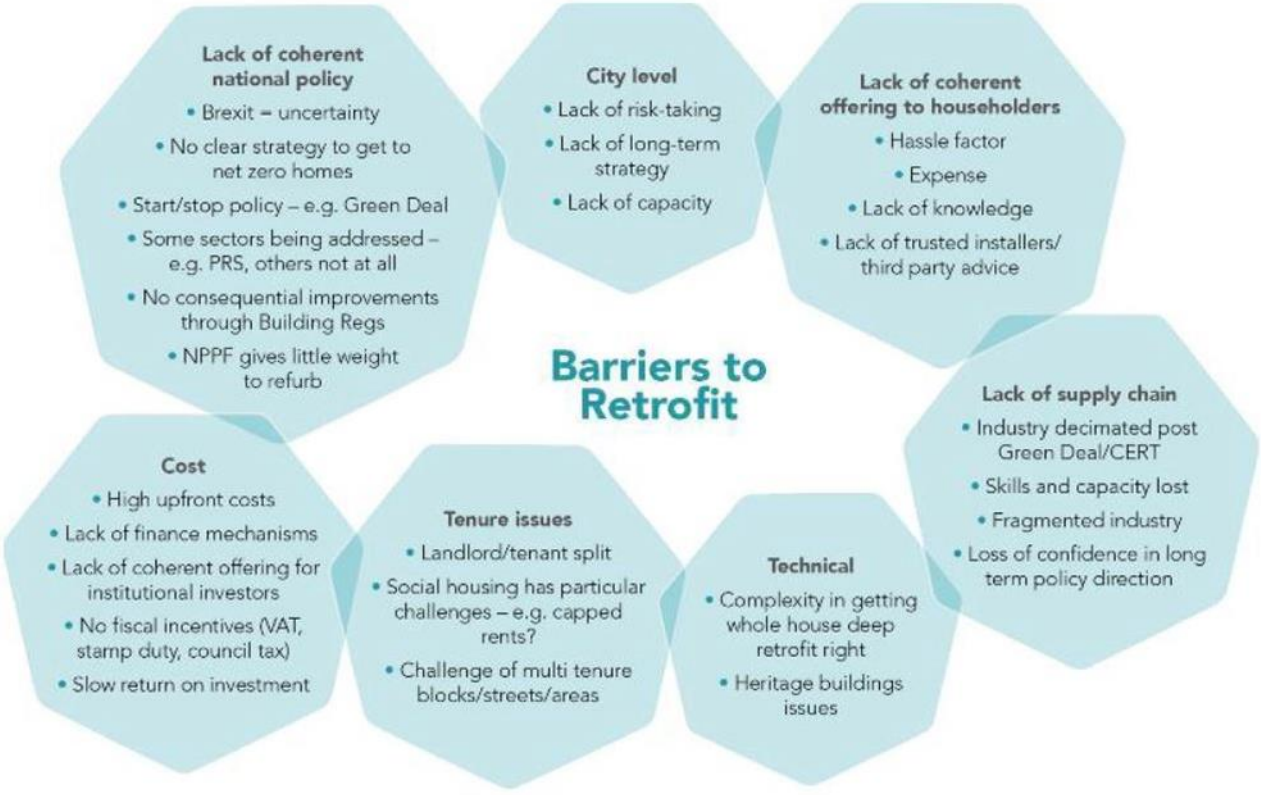
Barriers to retrofits in social housing

The academic literature, industry insight and government-commissioned policy analysis identify the following barriers to social housing retrofits.

In their international review of 67 articles published between 2000 and 2016, McCabe, Pojani, and van Groenou (2018) highlight the following barriers to the adoption of renewable energy in social housing: 1) lack of resident engagement; 2) a poor understanding of users; 3) financial risks; 4) organisational hindrances, such as risk aversion and lack of capacity for innovation, siloed workstreams, and inadequate inter-organisational cooperation; 5) inadequate policy support and funding; 6) technological complexities

Concerning the housing sector at large, the UK Green Building Council (UKGBC) and the European climate transition innovation agency EIT Climate-KIC highlight the following barriers (Figure 2).

Figure 2 - Barriers to retrofits in the UK housing sector. UKGBC & EIT Climate-KIC, 2019



Identified barriers to retrofit – EIT Climake KIC & UKGBC Accelerator Cities Pathfinder Project

Likewise, the Green Finance Institute identifies the following financial and socio-technical barriers to retrofits in social housing (Figure 3).

Figure 3 - Financial and non-financial barriers to social housing retrofits in the UK (Green Finance Institute, 2020, p.32)

Financial Barriers	Non-Financial Barriers
• **Limited funds:** New construction and renovation of existing stock compete for small budgets in Councils. • **Access to capital** is acute in smaller RSLs. • **Bureaucracy:** Financing models for renovation projects have long lead-times for approval. • **Planning horizons:** Short-term government grant programmes are difficult to reconcile with longer-term stock improvement plans. • **Interest rates:** Housing associations have the highest share of stock and face higher borrowing rates than local authorities.	• **Supply chain constraints:** Renovation on the scale needed, at an acceptable cost, cannot be routinely relied upon. • **Project development, delivery expertise and capacity** often in short supply at many Councils and smaller housing associations, where capacity struggles to match net-zero ambitions and complexity of renovation projects. • **Reluctant private leaseholders** in flats and terraces are rarely compelled to permit or contribute to changes, which can suppress economies of scale. • **Multi-property retrofits impacted by Right to Buy,** such that a portfolio of properties is not centrally controlled.

Another key barrier to the adoption of deep retrofits is the observed *lack of impact data and complete evaluations* of demonstrator programmes in the UK as elsewhere (Krizmane, Borodinecs, & Dzelzitis, 2016). Although insightful, the projects reviewed in this report provide scant and unsystematic information about projects performance and long-term outcomes. This is probably due the 'projectification' of domestic retrofits and limited data availability due to commercially and financially sensitive nature of the information.

Research aims

The research aims at establishing the state of the art in energy-efficient retrofits in social housing. It investigates the multiple socio-technical factors that influence the design, adoption and evaluation of different retrofit measures, including innovative partnership arrangements that can further these in the future.

Ten research questions underpin this research aim:

1. What are the **opportunities and barriers** to energy-efficient retrofits in social housing, particularly in the UK?
2. How can social housing contribute to achieving **net zero carbon targets** in the built environment? How can social housing retrofits **resolve performance gaps**?
3. Which **policy incentives** and **best practice guidance** can support retrofit innovation at present and in the future?
4. What are the relative advantages and challenges of **deep vs. incremental** approaches to retrofits in social housing?
5. Which **finance and business models** exist at present that can deliver retrofits in innovative ways?
6. Which multi-organisational **partnership arrangements** currently exist that can deliver retrofits in innovative ways?
7. Which are the main technologies available in terms of **fabric**, **renewable energy and monitoring** of energy consumption and indoor environmental quality?

8. What role can **emerging technologies** and processes such as modern methods of construction (MMC) and BIM play in delivering more cost-efficient and effective retrofits?
9. What are the most effective ways to **engage tenants/residents** in social housing retrofits? What are the opportunities in terms of community building, jobs, and skills transfer, and fostering sustainable lifestyles?
10. Which are the main **legal** considerations for retrofit innovation? How can cross-tenure retrofit programmes be delivered most effectively?

Based on the above, a final research question concerns how to best coordinate the interlocking socio-technical factors that underpin successful retrofit innovation:

> How can retrofits in social housing be **re-conceptualised to better manage the complex interdependencies** between the different socio-technical components, and bridge theory and practice?

Critically, the report identifies pending gaps in knowledge across all of these areas, with a view to deploy a portfolio of innovative demonstrators to support experimentation, benchmarking and extensive knowledge sharing across the social housing sector in the UK and beyond.

Methods

The state of the art is based on a desktop review of policy documents, industry recommendations and case studies, and the academic literature on energy efficient retrofits in social housing. Case studies focus on demonstrator projects at the Green Futures Partnership (GFP), and other demonstrator projects and programmes across the UK and Europe. Due to time constraints, the report relies entirely on secondary data and existing literature. Hence, no primary data was collected. The reviewed literature covers such topics as business models, a range of individual and comprehensive retrofit technologies, carbon assessments, digital technologies, tenant engagement and behaviour, regulation and standards, intra- and inter-organisational workflows, financial incentives and sources of funding, value creation and industry-led frameworks. While the review primarily focuses on empirical evidence and policy orientations, some theoretical papers are also considered where relevant. The selection of literature adopted a combined purposive and snowballing approach to provide a picture of the identified and emerging conditions and enablers to affordable social housing retrofits (Etikan, Alkassim, & Abubakar, 2016). A purposive sampling approach targets sets of cases and/or people that display specific characteristics of interest (Etikan, Musa, & Alkassim, 2015); here, these primarily concern energy-efficient social housing retrofits. The literature review also considered new-builds / social housing developments, student housing retrofits and sustainability innovation to the extent that they provided transferable insight about such themes as: modern methods of construction (MMC), exemplar customer engagement, Building Information Modelling (BIM), and innovative business models. Based on the purposive sample, snowballing was also applied: the projects we identified often cited other noteworthy projects that we investigated, as relevant. By collecting insight about cases among GFP demonstrators and other demonstrators across the UK and Europe, the review enables a preliminary case survey method, which seeks to aggregate insight from several case studies based on a consistent sampling approach (W. A. Lucas, 1974).

Altogether, the review serves as a basis for the development of a conceptual framework and research agenda to further advance the field of energy-efficient retrofits in social housing. Academically, it maps a range of opportunities for novel contributions to knowledge. Practically, it identifies a range of opportunities for public private partnerships and innovation consortia to pilot a new generation of cost-efficient, ‘net-zero’ and/or ‘nearly-zero’ energy retrofit solutions for social housing in the UK and beyond.

Context and policy overview

This section maps the historical and contemporary policy context for net-zero carbon performance in social housing retrofits since the beginning of the millennium. It begins with an overview of Local Agenda 21 programmes to gain a better perspective of the cross-cutting policy issues that affect the

uptake of energy-efficiency measures, and which are regaining momentum due to declarations of climate emergency across the country. It then considers the successive waves of energy-efficient policies to this day, as well as guiding policy documents and frameworks. The section closes with key policy recommendations produced by various industry leaders. The latter highlight map out both key challenges and emerging opportunities toward best practice in energy-efficient retrofits in social housing. In all, the section addresses both contextual and specific policy issues that underpin successful efforts toward energy-efficient retrofits in social housing.

Fuel poverty

Alleviating fuel poverty is one of the most common goals of energy-efficient retrofits. Critically, fuel poverty can negatively impact people's physical health and subjective well-being, and induce an ethic of 'frugal' living, notably among older people (Anderson, White, & Finney, 2012; Awaworyi Churchill, Smyth, & Farrell, 2020; Liddell & Morris, 2010). Official government data from 2018 indicates one in ten UK households (2.7 million households) can be classified as 'fuel poor', meaning "their fuel costs are above average, and their disposable income (after housing and fuel costs) is below the poverty line."[3] The majority of fuel poor households live in a property with EPC Band D. In parallel to ongoing efforts to address fuel poverty and energy-efficiency simultaneously, the Decent Homes Standard will be under review between 2021 and 2022 to assess the relevance of the current definition of 'decent homes'[4] The Sustainable Warmth report by BEIS (2021) provides a Fuel Poverty Strategy by way of twenty-one commitments to continue to tackle and monitor progress in alleviating fuel poverty.[5] Fuel poverty can be closely related to poor home quality and a range of significant health hazards. Poor home quality was estimated in 2016 to cost up to £1.4 billion to the NHS and £18.6 billion to wider society.[6] In Wales, 238,000 homes were estimated to feature Category 1 Housing Health and Safety Rating System (HHSRS) hazards based on data for 2017-8, with an estimated cost of minimum property upgrade of £2.455 per home.[7] Of direct relevance to fuel poverty, the report states that "the costs of improving cold homes are some of the most expensive, but also the most effective in reducing costs to the NHS" (Nicol, Garrett, Woodfine, Watkins, & Woodham, 2019, p. ii). In their report to the UK Committee on Fuel Poverty, Bridgeman and colleagues (2018) at the Centre for Sustainable Energy provided a thorough overview of what fuel poverty is, including challenges and opportunities for tacking fuel poverty across the UK housing sector.[8]

There has been some debate as to whether measurements of fuel poverty should be *relative* (i.e. considering the distribution of income, poverty and fuel costs to households across society) or *absolute* (e.g. as a percentage of income). Given the volatility of fuel prices, a relative measurement may be appropriate to assess overall poverty across society but not fuel poverty specifically. Therefore, a calculation of fuel poverty based on a minimum income standard (MIS), or a 'low income / high energy cost' approach, is meaningful; however, fuel poverty threshold should account for fuel costs relative to the thermal performance of the property (e.g. below EPC band C) (Moore, 2012). Investigating the overlaps between three different fuel poverty indicators in the UK, Deller et al. (2020)

[3] See the Annual Fuel Poverty Statistics Report 2020 (based on 2018 data): [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882159/fuel-poverty-factsheet-2020-2018-data.pdf]

[4] See the announcement of the review of the Decent Homes Standard [https://www.gov.uk/guidance/decent-homes-standard-review]

[5] The Fuel Poverty Strategy ('Sustainable Warmth' report) published by BEIS (2021) can be found here: [https://www.gov.uk/government/publications/sustainable-warmth-protecting-vulnerable-households-in-england]

[6] See a summary of the report by Mike Roys and colleagues (2016) on the BRE website [£35 fee to download the actual report]: [https://www.bregroup.com/buzz/the-full-cost-of-poor-housing/]

[7] See the report by Nicol et al. (2019) for BRE and the Welsh Government: [https://phw.nhs.wales/news/the-cost-of-poor-housing-in-wales/the-full-cost-of-poor-housing-in-wales/]

[8] See the report by the CSE (2018) here: [https://www.cse.org.uk/downloads/reports-and-publications/fuel-poverty/policy/insulation-and-heating/policy-tensions-and-synergies-CFP-mainreport-may-2018.pdf]

report little overlap between income-based and perception-based indicators, showing also that 'fuel poor' households may not perceive themselves as such. Fuel poverty assessments should therefore consider occupants' perceptions and heating preferences alongside other measures such as actual temperatures in homes and income levels. Fuel poverty is largely in the eyes of the beholder; the practice of data collection, and the quality and extent of available data, all shape how fuel poverty is construed and acted upon. Going forward, "energy poverty measurement will necessarily become participatory" (Sareen et al., 2020, p. 34)). A more participatory approach to fuel poverty identification and alleviation can have far-reaching implications in terms of knowledge claims and sharing, policy efficacy, not to mention the efficiency and social value of retrofit investments. Residents' involvement is particularly important considering the enduring lack of consistency and agreement in both policy and research about how to best measure and deal with fuel poverty (see Primc, Dominko, & Slabe-Erker, 2021).

Estimations of fuel poverty also go hand-in-hand with efforts to treat it. In Wales, for example, an assessment report[9] of the extent of fuel poverty in 2012 was held in conjunction with the launch and continuous assessment of the NEST (2011-ongoing) and Arbed (2010-2015) Warm Homes renovation schemes aimed at low-income households (Grey, Jiang, & Poortinga, 2015). The latest annual assessment report for NEST indicates that "As the current Welsh Government Warm Homes Nest scheme enters its third year in 2020-21, the need to tackle fuel poverty and help those most in need is still as important as it has ever been."[10] Likewise, across the UK, fuel poverty assessments underpin the development, monitoring and assessment of BEIS-led schemes such as ECO and the Warm Homes Discount, among others.

The above demonstrates fuel poverty is both deeply entrenched and more nuanced than commonly acknowledged in policy and technical interventions that focus primarily on the physical characteristics of properties. These also indicate the need for a systemic, socio-technical approach to delivering thermal performance and guarantees of thermal comfort in homes that need it the most.

Government incentives

Over the last twenty years, the UK government has issued a number of energy-efficiency incentives that have not quite delivered according to expected volumes or performance levels. Currently, it seems that the many of the opportunities for low-cost investments to leverage high returns in the lowest performing homes have been met. Combined with declined government funding and poor incentives for homeowners to invest in energy-efficiency measures, the RIBA (2020) highlights the UK government needs to provide both coherent policy and more up-front funding to meet the legally binding net-zero carbon targets in 2050. At present the UK housing stock is one of the least energy-efficient in Europe. At the same time, social housing "is already outperforming other tenures in terms of energy efficiency", even in the absence of a clear, comprehensive Government strategy and policy framework (RIBA, 2020, p. 42).

Green Homes Grants – Local Authorities Delivery (LAD) scheme

The Green Homes Grants Local Authority Delivery (LAD) scheme[11] is a £500m, fast-tracked policy scheme launched in 2020 to improve energy efficiency (insulation and low-carbon heating) and create jobs in times of covid. The scheme is open to all forms of tenure, and targets low-income households (with an income under £30,000/y) who live in properties with EPC bands E to G, as well as some D

[9] See the Welsh government's Fuel Poverty Evidence Plan (2012), which set out the need for continuous monitoring as part of its vulnerable home renovation schemes: [https://gov.wales/sites/default/files/publications/2019-06/fuel-poverty-evidence-plan.pdf]

[10] See the NEST annual report for 2019-2020 (Welsh Government 2020, p.20): [https://nest.gov.wales/workspace/uploads/files/nest-annual-report-english-5f5b522fc5fc2.pdf]

[11] The information is based on a presentation by Kate Duffy, senior policy advisor at BEIS, on 25 March 20201 at the online Retrofit Academy CIC 'Retrofit for Social Housing Summit'[starting at 59:00 in the video recording]: [https://www.youtube.com/watch?v=Nh0gnPjtQ-Y].

ratings if present as part of bulk property retrofits. The scheme featured 2 main phases, with Phase 2 requiring PAS 2035 (including retrofit coordinators) and 2030 (i.e. TrustMark accreditation for builders). Many local authorities from the first phase applied for extensions into Phase 2. Besides home renovations, the scheme also funded the creation of five local energy hubs across England. Although phase 1 was initially undersubscribed, the scheme succeeded in getting a fair geographical spread across England. Importantly, there were delays in delivery due to covid and tenants feeling uncomfortable allowing tradesmen into their homes at the peak of winter and during covid lockdown.

Table 1 – GHG LAD phases

LAD phase	Homes (n)	Projects (n)	Total £	LA.s (n)	Delivery	Note
Phase 1a	10,000	55	£74m	100	End 2020	Undersubscribed
Phase 1b	15,000	81	£126m	200	Sept 2021	Crossovers (P1a)
Phase 2	~30,000	*n/a*	£300m	*n/a*	Dec 2021?	→ Energy hubs
Total	~55,000	*n/a*	£500	*n/a*		

Importantly, individual households could not benefit from cross-funding (e.g. both LAD and Green Homes Grants *vouchers*). However, contractors may install energy-efficiency measures funded by separate schemes (e.g. heat pump installation through LAD and solid wall insulation through ECO).[12]

Up to fifteen percent of the grant could be used for project management, various ancillary works and other support for the low-income households. This indicates some learning from former schemes (e.g. Green Deal Communities 2013-2016 – *see below*), where insufficient funding was allocated to support the design, supply-chain development, management and delivery of the energy efficiency measures.

Social Housing Decarbonisation Fund (SHDF)

In October 2020, £62m were awarded to 17 local authorities for 19 projects. The SHDF Demonstrator project will bring a total of 2.300 homes to EPC band C or higher, with completion expected for December 2021. It is expected the scheme will be renewed as £60m have been earmarked for 2021-2022. The projects "will demonstrate innovative approaches to retrofitting social housing at scale, using a whole house approach".[13] The successful bids[14] concern local authorities of different sizes across the UK, with retrofit interventions featuring a mix of fabric improvements (typically EWI, window glazing, sometimes with floor insulation), low-carbon heating (heat pump) and/or solar panels.

Sixth Carbon Budget

The National Housing Federation (NHF, 2021) provides a bespoke summary of the Sixth Carbon Budget (running 2033-2037) produced by the UK government's Climate Change Committee. Particularly for social housing, all social homes should be brought to EPC band C by 2028. Some of the key net zero pathway milestones include: 1) all new buildings are zero carbon by 2025 at the latest; 2) All rented homes achieve EPC band C by 2028; 3) lenders should target properties with

[12] See the disambiguation provided by the Energy Savings Trust (2 October 2021): [https://energysavingtrust.org.uk/report/green-homes-grant-local-authority-delivery-scheme/]

[13] Notice on the Department for BEIS website (23 March 2021): [https://www.gov.uk/government/publications/social-housing-decarbonisation-fund-demonstrator-successful-bids]

[14] List of winning bids in the first iteration of the Social Housing Decarbonisation Fund: [https://www.gov.uk/government/publications/social-housing-decarbonisation-fund-demonstrator-successful-bids/social-housing-decarbonisation-fund-demonstrator-successful-bids]

EPC band C between 2025 and 2033; 4) and all homes for sale should be EPC band C by 2028. Other milestones include the energy mix of energy supply.

Home Energy Efficiency Programme for Scotland (HEEPS)

The Scottish government issued a number of grants for social landlords to improve the energy efficiency of their housing stock. In the period between 2013 and 2019, the area-based HEEPS delivered energy efficiency measures to 78,000 homes worth £325 million.[15]

Green Deal (GD) Communities

Initially planned for a single year, the Green Deal communities scheme ran 2013-2016 and amounted to £88 million of funding to support energy efficiency and renewable energy measures, mostly for the private housing sector. Twenty-four local authorities directly took part, but combined with other funding streams, a total of one hundred local authorities could benefit from the scheme. A learnings event was held in January 2017 to share experiences of success and shortcomings. A summary report provided key recommendations endorsed by the majority of participants, and additional suggestions (Preston & Mallett, 2017). Recommendations cover programme design, policy, householder engagement, and supply chain. In terms of *programme design* specifically:

- The need for *clear project objectives and whole evaluation processes* underpinned by consistent indicators for benchmarking. Particularly, “the experience of those involved with on-the-ground delivery who have worked with a range of contractors and householders should not be under-estimated” (p.5).
- *Appropriate, project-specific timescales and delivery timelines* that account for technology maturity, design and installation know-how, and seasonal climate.
- *A phased approach to funding and project development*. Phases can comprise: *1) data gathering and feasibility → 2) procurement → 3) marketing → 4) delivery*. A phased approach can be streamlined more quickly with accrued project experience. For example, installation know-how and supply-chain procurement for solid wall insulation may take time for first-time adopters.

Investigating the effects of the Green Deal Communities programme at the London Borough of Haringey, Ince and Marvin (2019) argue the programme was ill-coordinated with other retrofit and regeneration policies at the council, leaving many fuel poor households without access to much-needed home improvements, most notably social tenants. Some local supply chain was put in place to help deliver the aims of the programme that retrofitted 1,000 properties. However, the narrow eligibility conditions, limited timeframe for the government funding, market-focused and technology-driven logic of the retrofits were not successful in tackling local inequalities at the council, reputed to be one with the highest income disparities in Greater London. As a result, the retrofit ‘infrastructure’ which large retrofits can otherwise leverage was incomplete and temporary in nature in Haringey, in contrast to Green Deal communities in Greater Manchester and Nottingham (Ince & Marvin, 2019). The centralised approach to GD promotion and delivery in Birmingham led to the missed opportunity of structuring and strengthening the value chain among local contractor SMEs (Watson, 2014).

Additional policy suggestions include:

- Varying/sliding stamp duty rates based on EPC bands to further incentivise deeper whole-house retrofits.
- Develop the solid wall insulation supply chain through investment, training, quality, and greater local sourcing of suppliers and contractors by improving the skills base.

[15] See details of the area-based Home Energy Efficiency Programmes for Scotland (2013-2019): [https://www.gov.scot/publications/home-energy-efficiency-programmes-for-scotland-area-based-schemes/]

- Promote a wider range of alternative and complementary funding options: credit unions managing revolving loan funds, green mortgages, repayments tied to the land registry, energy performance contracts, and a better pay-as-you save loan.
- In the absence of accurate energy savings estimations, highlight other benefits such as warm and healthy indoor environments and increased property prices to help incentivise investment for solid wall insulation.

Green Homes Grants Scheme

Like the Green Deal Communities scheme, the Green Homes Grant Scheme targeted homeowners. Notwithstanding, the key learnings from the scheme indicate the need for more training, a better supply chain, and more consistent policy in Britain, which will necessarily affect opportunities for net-zero retrofits in social housing.

The £1.5 billion scheme to help 'build back better' was scrapped in March 2021, having been initially heralded as one of the most ambitious in years.[16] The scheme's launch and demise were widely discussed in the media. Only 5,800 homes benefitted from energy efficiency measures, compared to 123,000 applications. Harriet Lamb, CEO at Ashden, views it did not deliver as per plan due to three main factors: 1) *a lack of 'net-zero' craftmanship* among building trades; 2) *a lack of trained retrofit coordinators* (currently 500, but 36,000 will be needed to reach long-term net-zero targets); and 3) a *lack of consistent government policy* to roll-out effective energy efficiency measures at the required scale.[17] Beyond the scheme, the PAS 2030 training accreditation can improve know-how among builders and provide guarantees to homeowners and housing providers procuring retrofits.[18]

Looking ahead: future funding

Overview. Kate Duffy at BEIS provides an overview of current and future funding streams.[19] These include the Social Housing Decarbonisation Fund (SHDF), the next phase for the Green Homes Grant Local **Authorities** (LAD) scheme, and various other grants for home improvements in low-income households, including homeowners, that can be used to fund cross-tenure retrofit schemes. Public funding allocated from 2021 will require PAS 2035, focusing on making the greatest improvements from the least energy-efficient homes. Overall, publicly funded retrofits will necessarily be incremental: it won't be possible to retrofit all homes simultaneously with public investment alone. Peter Rickaby, technical lead author of PAS 2035, calculated that an optimal average of £25,000 investment for the 25 million dwellings that require retrofits would amount to a total collective spending of £624 billion across UK society, which the government alone could never bear. The 'Sustainable Warmth' strategy[20] (see also the next section 'Guiding policy documents') highlights the importance of retrofits. Multiple funding streams will support the strategy. Altogether, they can either fund social housing directly, or benefit the sector indirectly by developing economies of scale, improving training and skills, and creating integrated supply chains at the local level. Greater market maturity could therefore decrease reliance on government funding in the future. As would the emerging role of green finance.

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[16] Review by Fiona Harvey in the Guardian (March 27th 2021) [https://www.theguardian.com/environment/2021/mar/27/uk-government-scraps-green-homes-grant-after-six-months]

[17] Ashden supports local climate actions worldwide. Its yearly award helps to showcase exemplar actions. In the UK, these include the Ashden awards for 'climate innovation' and 'green communities' [https://ashden.org/news/green-skills-shortage-could-thwart-our-climate-commitments/].

[18] Advice by Ian Preston of the Centre for Sustainable Energy: [https://www.cse.org.uk/news/view/2584]

[19] See the presentation at the 'Retrofit for social housing summit' hosted by the Retrofit Academy 25 March 2021: [view at 1:10:00] [https://www.youtube.com/watch?v=Nh0gnPjtQ-Y]

[20] The Sustainable warmth strategy was published 11 February 2021: [https://www.gov.uk/government/publications/sustainable-warmth-protecting-vulnerable-households-in-england/sustainable-warmth-protecting-vulnerable-households-in-england-accessible-web-version]

Energy Company Obligation (ECO). ECO committed to extend funding until 2026, with spending increased from £640m to £1bn/year. It will do so under a single obligation: the Home Heating Cost Reduction Obligation (HHCRO) will see that obligated suppliers "mainly promote measures which improve the ability of suppliers targets low income, fuel poor and vulnerable households to heat their homes."[21]

Innovation Partnership. The new £10bn scheme launched by the London mayor will deliver social housing retrofits across GLA and will also be open to social landlords across the UK, starting this summer.[22] It aims to create around 150,000 jobs to decarbonise the social housing stock, reduce energy bills and alleviate fuel poverty. The scheme will likely improve the skills base and labour force to deliver retrofits at scale, which will likely help structure the retrofit market and strengthen local value chains for the wider housing sector.

The Shared Prosperity Fund will replace EU structural funding going forward, as of 2022. While still uncertain, the Fund would likely support retrofits across the country, including through Local Entreprise Partnerships. Critically, retrofit approaches that aim for subsidy-free upscaling such as Energiesprong still heavily rely on grant funding until market maturity is achieved. Going forward, these approaches will likely continue to rely on structural funding. In the run-up to the publication of the Investment Framework for the Shared Prosperity Fund, three funds will support local communities: 1) the UK Community Renewal Fund;[23] 2) the Levelling Up Fund;[24] and 3) the Community Ownership Fund.[25]

Medium-term and long-term funding. Vivid Economics and Connected Places Catapult (2021) provide a thorough overview of current public funding (p. 65) and long-term funding and financing opportunities for market innovation and maturity until 2040 (pp. 46-50) to meet net zero carbon targets in the UK residential sector. The report emphasises the importance of public-private partnerships and experimentation with innovative financing mechanisms.

UK policy context

The national policy landscapes for climate transition and energy efficiency are complex and interdependent. This section provides a selective overview.

The 'Ten Point Plan for a Green Industrial Revolution' by BEIS (2020) promotes both greener buildings and greener finance. If it follows through, it could help bring greater market maturity, supply chain integration, training and skills, and job opportunities to leverage cost-effective retrofit solutions across the housing sector, including social housing. Green finance, likewise, can generate both innovative and traditional investment streams (more below).

BEIS Sustainable Warmth: Protecting Vulnerable Households in England (2021). The Sustainable Warmth strategy seeks to reduce fuel poverty, lower energy bills and improve public health simultaneously. It details various grant schemes to fund energy-efficiency measures to alleviate fuel poverty, such as an expanded ECO, Warm Home Discount, Home Upgrade Grant,

[21] See the description of the ECO HHCRO by Ofgem which administrates the government's ECO scheme: [https://www.ofgem.gov.uk/environmental-programmes/eco/about-eco-scheme] [accessed 9 June 2021]

[22] See the news coverage of the new Innovation Partnership on Housing Executive [3 June 2021]: [https://housingexecutive.co.uk/khan-launches-new-10bn-partnership-to-retrofit-londons-social-homes/]

[23] See details of the £220 million UK Community Renewal Fund that "aims to support people and communities most in need across the UK to pilot programmes and new approaches and will invest in skills, community and place, local business, and supporting people into employment": [https://www.gov.uk/government/publications/uk-community-renewal-fund-prospectus]

[24] The cross-sectoral £4.8 billion Levelling Up Fund builds on the Towns Fund and Local Growth to strengthen all types of local infrastructure and regeneration efforts: [https://www.gov.uk/government/publications/levelling-up-fund-prospectus]

[25] The £150 million Community Ownership Fund is meant to support community asset transfers to run as community-owned businesses: [https://www.gov.uk/government/publications/community-ownership-fund]

Green Homes Grant, and further encourage the private sector to invest in energy efficiency. Additionally, it seeks to improve standards definitions through the Future Homes Standard (concerning new build) and the Decent Homes Standard that is currently out for consultation. The strategy defines a fuel poverty target for England to "ensure that as many fuel poor homes as is reasonably practicable achieve a minimum energy efficiency rating of Band C by 2030."

At the intersection between local plan making (which provides the frame of reference for local development), development management, building control and sustainable housing renovation, a number of policy tools can help leverage greater sustainability in the built environment at different spatial scales. These include the National Design Guide, the presumption for sustainable development in the National Planning Policy Framework, and the Planning for the Future white paper by MHCLG. Furthermore, many councils are adopting local climate action plans.[26] Both national and local government can play a role in delivering planning approval and building permission 'in presumption of favour' toward whole-house energy-efficient retrofits as these can benefit neighbourhood attractiveness, public health, legally binding low-carbon targets, and sustainable lifestyles simultaneously.

Standards, toolkits and frameworks

This section reviews noteworthy standards, toolkits and frameworks as well as best practice guidance by government and industry leaders. These are comprehensive/holistic rather than issue specific. Taken together, these provide important orientations and methodologies for future innovation in energy-efficient social housing retrofits. More than just a summary, this section engages with the documents critically to map a range of strategic pathways toward embedding greater sustainability in the existing social housing stock.

The Sustainable Renovation Guide

The 'Sustainable Renovation Guide' (Morgan, 2018)[27] provides a thorough yet accessible account of the technical as well as behavioural dimensions of ensuring thermal performance when renovating homes to low-energy standards. It covers building technologies and approaches, such as all types of fabric interventions. The report focuses on the Scottish context, but of UK-wide significance.

PAS 2035 – BSI

Published in 2019 by the British Standards Institute (BSI), PAS 2035 is probably the single most important framework for whole-house retrofits in the UK. PAS 2035 incorporates the insight from the 'Retrofit for the Future' programme of energy-efficient housing retrofits (2010-2014). It is a best practice framework, not a BSI Standard. The recommendations in PAS 2035 incorporate key learnings from what went wrong in the Retrofit for Future programme, as well as observed successes. The framework ensures users avoid the following mishaps: defects and unintended consequences in retrofits interventions, shallow (i.e. piecemeal and poorly scheduled) retrofits; poor accountability and responsibility; poor design; and performance gaps, where predicted savings are not delivered in practice. Contractors registered with TrustMark can help deliver PAS 2035 best practice. As of the first quarter 2021, all publicly funded retrofits *were to* comply with PAS 2035.

The framework endorses 6 core principles: 1) *professional accountability*; 2) *whole-house* retrofits 'over time', not piecemeal interventions; 3) *bespoke* projects that cater for the needs of each home; 4) *'Build tight, ventilate right'* to ensure thermal and indoor air quality; 5) *Quality* all the way, to achieve

[26] See the beta version of the online searchable database of local councils that have adopted climate action plans: [https://data.climateemergency.uk/]. The database is produced by mySociety and Climate Emergency UK Housing plays an important part of decarbonisation measures at the local level for which local councils have an active role.

[27] You can download the Sustainable Renovation Guide here: [http://www.johngilbert.co.uk/?p=16515]

performance and further build the market; 6) a **'***fabric first'* approach, relying on fabric/envelope improvements before introducing any new energy system(s).

To ensure its effectiveness, every PAS 2035 certified project must feature a qualified retrofit coordinator (e.g. trained by the Retrofit Academy), who is to oversee effective data sharing, professional responsibilities and accountability arising from new roles, risk assessments, retrofit plans, design input (e.g. by architects, surveyors, etc.), process integration, soft landings, and continuous monitoring and evaluation, with the aim of minimising performance gaps. In sum, PAS 2035 requires extensive collaboration and communication among all involved parties.

Net-zero carbon buildings: A framework definition – UKGBC (2019)

The introduction to this report provides definitions for construction net-zero, operational net-zero, and whole life cycle net-zero produced by the UK Green Building Council (2019). Based on these, the report proposes a framework to embed these in project design, implementation and evaluation. The framework comprises five key steps of relevance to both new builds and renovations:

1. **Scoping**: establishing net zero carbon at construction and operation
2. **Reducing construction impacts,** adopting a whole life cycle approach that considers both embodied energy and the construction process
3. **Reducing operational energy use:** prioritising reductions in energy demand, and providing including yearly disclosure of energy use monitoring
4. **Increase renewable energy supply**: on-site generation or low-carbon energy supplier
5. **Offset any remaining carbon**

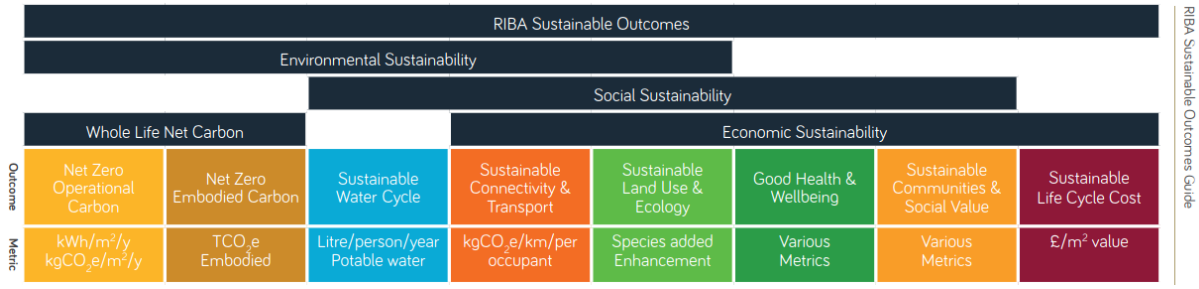
Together with partners[28], the UKGBC also produced a useful one-page overview of the ten requirements for net-zero operational carbon and their respective indicators.

RIBA Sustainable Outcomes Guide (2019)

The landmark Sustainable Outcomes guide published by the RIBA (2019) provides key performance-based goals and indicators to overcome the all-too-common performance gap in both new build and retrofits. To do so, the guide helps to operationalise the UN Sustainable Development Goals (SDGs) by translating them into key sustainable outcomes (SDGs 3, 6-9, 11-13, and 15) (RIBA, 2019, p. 8). As a comprehensive guide, it goes beyond carbon-only indicators and considers wider sustainability, including social value, health and well-being, sustainable water use, and biodiversity. The guide also provides a 'Core Sustainable Outcomes Target' in the form of a wheel diagram (RIBA, 2019, p. 11), and a thorough list of readily-available Sustainability Assessment and certification tools, ranging from BREEAM and BRE Home Quality Mark, to process tools such as the RIBA Plan for Use and the Soft Landings framework (RIBA, 2019, p. 14).

[28] See the A4 summary of the ten requirements for net zero operational carbon for new buildings (UKGBC-Net-Zero-Operational-Carbon-One-Pager.pdf) which are also useful to consider for retrofits. Partners included: London Energy Transformation Initiative, UKGC, Better Buildings Partnership, Good Homes Alliance, RIBA, and CIBSE.

Figure 4 - the RIBA sustainable outcomes per category with associated indicators (2019, p.8)



RIBA Greener Homes: Decarbonising the housing stock (2020)

The report advocates for a National Retrofit Strategy as a "long-term policy and investment programme for upgrading the energy efficiency of England's housing stock" (RIBA, 2020, p. 4). This will compensate for the fact that the UK Government does not have a comprehensive, cross-departmental plan to leverage the Clean Growth Strategy. The report suggests the government should front-load £9.2 billion to fund energy efficiency over a ten-year period. Among other measures, the report suggests energy efficiency should be embedded across the whole tax system, with a caveat for VAT: it is not certain that VAT cuts would be effective, even though current VAT for new homes is zero-rated, while VAT is set at 20 per cent for energy efficiency measures. Also, existing fuel poverty schemes should prioritise energy efficiency.

To support better design and monitoring of energy-efficiency measures, the report highlights that EPC-based Standard Assessment Procedure (SAP) and reduced data SAP (rdSAP) estimations of energy savings are imprecise and therefore not fit-for-purpose. Instead, energy efficiency should be measured based on actual energy usage. As the EPC system has gained significant public awareness over the years, it should be improved rather than scrapped.

RICS Futures Report (2020)

The RICS Future Report (2020) lays out the action agenda for chartered surveyors. It comprises three core areas: 1) data and technology; 2) sustainability; 3) talent and skills. It is more limited in scope than other frameworks cited here, but worth citing given RICS' strong international focus and technical expertise as a professional body.[29] Furthermore, these identified needs overlap with the most recent policy and industry reports cited in this report, that map related opportunities and challenges for delivering social housing retrofit innovation at scale.

Passivhaus

The Passivhaus standard is an internationally acclaimed standard that combines low energy use and high environmental quality and comfort for occupants. It is most predominant in Germany and Austria. The original standard typically applies to new build and denotes "a building in which thermal comfort can be achieved solely by post-heating or post-cooling the fresh air flow required for a good indoor air quality, without the need for additional recirculation of air." To increase its relevance for retrofits, the EnerPHit standard was developed to leverage combined low energy use and thermal comfort for all types of building renovations, including social housing.[30] Although a leading standard, surprisingly few projects concern social housing retrofits, particularly in the UK, as observed by Sherriff, Martin, and Roberts (2018).

[29] RICS' identified areas for future development for a sustainable built environment: https://www.rics.org/uk/news-insight/future-of-surveying/

[30] Find out more about the specifics of the EnerPHit Standard for housing retrofits on the Passivhaus UK Trust's website: [https://www.passivhaustrust.org.uk/competitions_and_campaigns/passivhaus-retrofit/]

The number one landmark Passivhaus social housing retrofit probably is Wilmcote House in Portsmouth, which was the only UK project for the European-wide, EU-funded EnerPHit programme. Wilmcote House is a deep, stepwise retrofit that generated a lot of insight in terms of process, featuring ample technical difficulties, delays in delivery, significant disruptions to occupants who were not decanted, as well a change in contractor mid-way through the process (ECD Architects, 2018).[31]

A number of landmark Passivhaus developments are also worth mentioning: affordable and social housing new builds at Exeter City Council,[32] the award-winning Goldsmith Street social housing development at Norwich City Council,[33] and the Agar Grove estate redevelopment at Camden Council.[34] These cases, among other exemplar projects, target high-quality design, energy-efficiency, a user-centred approach underpinned by customer involvement and satisfaction, public realm interventions for wider community impact, and/or innovative offsite construction methods.

The UK also boasts a number of local adaptations of the Passivhaus standard. Largely based on the Passivhaus certification, Hastoe Group has recently launched its own New Build Standard.[35] Positioned as a rural social housing provider, Hastoe's new standard complies with the UK government's Future Buildings Standards (by 2025) and net zero carbon targets (by 2050), potentially making its developments likely candidates for several criteria of Paragraph 79 of the National Planning Policy Framework, which regulates planning permission constraints for new homes in rural settings. Besides energy performance, Hastoe's standard also favours lower water consumption, which is explicitly encouraged in the RIBA Sustainable Outcomes Guide and the ESG Reporting Standard. The standard can be traced back to the successful first experience at the Wimbish Passivhaus Development between 2011 and 2017.[36] Likewise, Beattie Passive is a flexible energy-efficiency standard for all types of homes, including its own brand of modular housing units ('Haus4') ranging from studios to two-bed modular homes, and relocatable hospital discharge home units.[37]

Living Building & Community Challenges

The International Living Future Institute provides a number of state-of-the-art standards to help design and deliver projects that are "socially just, culturally rich and ecologically restorative." Their methodology applies at a wide range of scales, from products to communities. The Living Building Challenge[38] is articulated around place, water, energy, health and happiness, materials, equity and beauty. As such, it overlaps with and can strengthen other frameworks reviewed here. The Living Community Challenge[39] upscales this approach to the level of neighbourhoods, districts and

[31] More information about the Wilmcote House EnerPHit retrofit can also be found here: [https://www.passivhaustrust.org.uk/news/detail/?nId=810#.W_1bM-j7Q2w]

[32] All developments at Exeter City Living are Passivhaus. See a showcase of Passivhaus developments at Exeter City Council published in 2016: [https://www.houseplanninghelp.com/wp-content/uploads/2016/09/Exeter-City-Council-Scheme-Information.pdf]

[33] See the acclaimed Goldsmith Street Passivhaus development of seven terrace blocks (2019): [https://www.architecture.com/awards-and-competitions-landing-page/awards/riba-regional-awards/riba-east-award-winners/2019/goldsmith-street]

[34] See the analysis of Phases 1A and 1B of the Agar Grove estate Passivhaus redevelopment by CIBSE (2020): [https://www.cibsejournal.com/case-studies/agar-grove-performance-assured/]

[35] See a description of Hastoe's New-Build Standard on their website [21 April 2021]: [https://www.hastoe.com/news/new-homes/raising-the-bar-on-energy-efficient-rural-homes-to-help-meet-zero-carbon-targets/]. The following Youtube video provides further illustrations of the standard: [https://www.youtube.com/watch?v=aHZclIAmn8w].

[36] See the following assessment documents about the Wimbish Passivhaus development, which was the first Passivhaus social housing development in rural settings: [http://www.wimbishpassivhaus.com/datasheets.html]

[37] See the complete range of Beattie Passivhaus homes: [https://www.beattiepassive.com/index.php]

[38] THE ILFI Living Building Challenge (2019): [https://living-future.org/lbc/]

[39] The ILFI Living Community Challenge (2017): [https://living-future.org/lcc/]

organisations. Underpinning these standards is the notion of *regenerative economy.* The Core Green Building[40] certification outlines 10 key features of sustainable buildings, which augments rather than replaces other standards such as BREEAM, LEED or Passivhaus. In such domains as water management and energy use, the ILFI standards advocate a 'net positive' rather than net zero approach. This takes stock of the dramatic environmental change that accompanies the current climate crisis, to provide operational tools for buildings and local economies that are positive and regenerative rather just 'carbon neutral' or 'passive'.[41]

Building Biology

The twenty principles of the Germany-based Institute for Building Biology complement the other frameworks reviewed in the report.[42] The standard prescribes a holistic human-centred approach and emphasises healthy indoor air, thermal and acoustic comfort, human-based design, sustainable environmental performance, and socially connected and ecologically sound communities. Because it encourages the use of more natural building and an overall high environmental quality, the approach may be more challenging to implement in areas exposed to substantial environmental pollution or retrofits in degraded properties that rely on the cheapest off-the-shelf materials. Adopters include housing providers. For example, all new development by Exeter City Living adopt Building Biology standards.[43]

SIRen

The SIRen methodology provides a design and evaluation model for energy-efficient refurbishments. The methodology can be used for a wide range of projects, including affordable and social housing retrofits. It is the product of extensive research and cross-industry collaboration with a view to identify key requirements and success factors to upscale a robust, energy-efficient decision-making model for retrofits. The radar chart assesses five key dimensions of retrofit projects for affordable multi-apartment housing (Figure 5), namely: 1) social, cultural and user considerations; 2) environmental considerations; 3) technical performance and quality; 4) investment and finance; and 5) process and coordination. As with PAS 2035 and other frameworks, the different components are interlocking rather than fully discrete, which entails advanced project coordination capacity as a condition for best delivery. Although developed for the Swedish built environment and affordable housing sectors, the model echoes with UK-based models, which both confirms and provides further inspiration for innovative, evidence-based retrofit approaches (Olander, Mjörnell, Femenias, Elisabeth, & Wallenten, 2019).[44]

[40] The ILFI Core Green Building Certification: [https://living-future.org/core/]

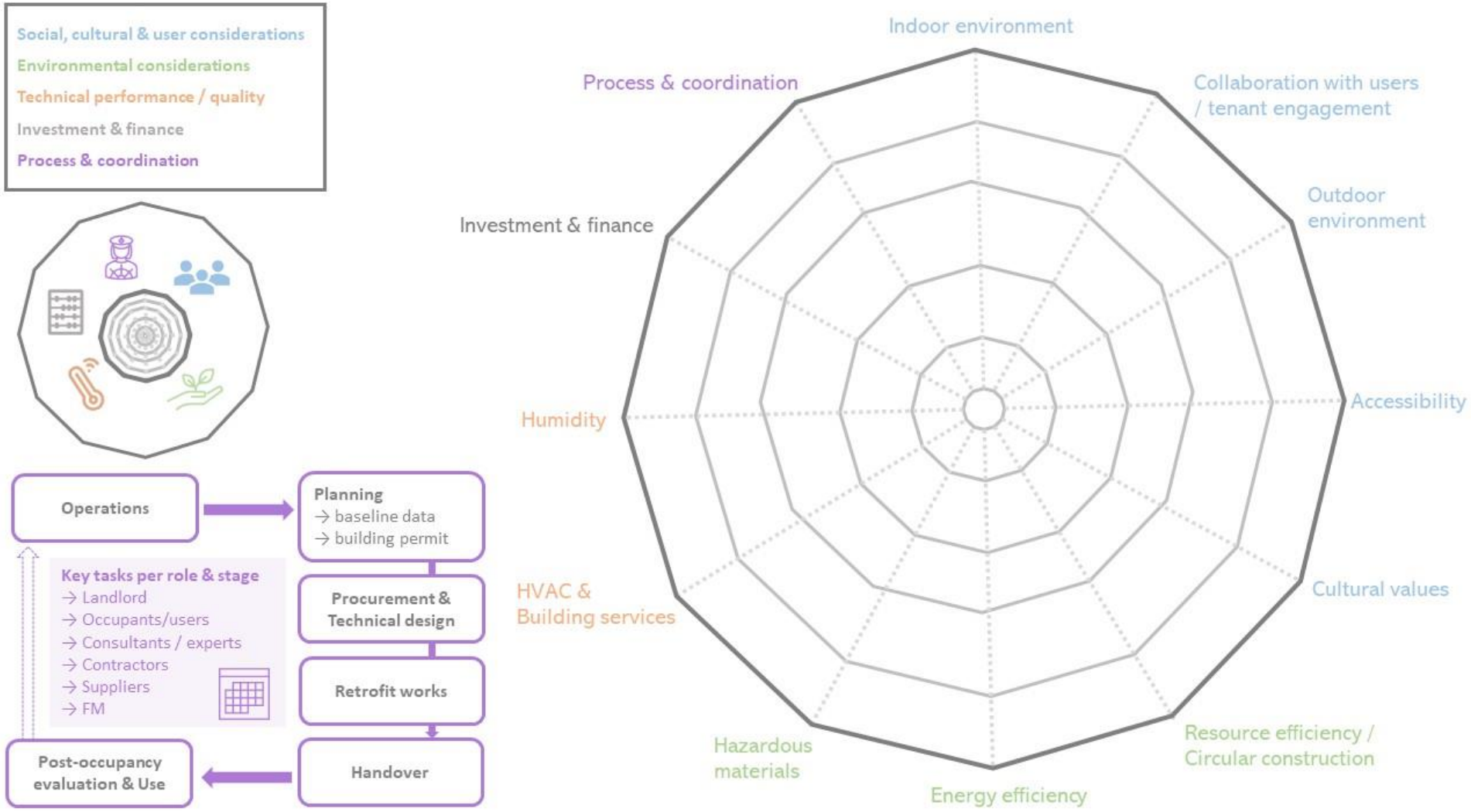
[41] The EU COST Action RESTORE programme has conducted extensive research work on the potential of the regenerative economy in the construction and housing sectors, that echoes with the work of the International Living Future Institute. See for example the 'Regenerative Construction and Operation' Final report (2019): [https://www.eurestore.eu/wp-content/uploads/2019/07/RESTORE-WG3-Booklet.pdf]

[42] See the 25 guiding principles of Building Biology here: [https://buildingbiologydotcodotuk.files.wordpress.com/2018/11/25leitlinien-handout-en-online.pdf]

[43] The landing page to the website of Exeter City Living presents their holistic approach: [https://exetercityliving.co.uk/]

[44] See also the repository of publications about SIRen about life cycle assessment and social value dimensions revealed during the programme (many of which are in English): [https://www.renoveringscentrum.lth.se/siren/publikationer/#c305800]

Figure 5 - Synthetic presentation of the SIRen methodology, with a simplified 'plan of work' in purple for the sake of brevity (Based on and modified from SIRen, 2019)



Process-based frameworks

The RIBA Plan of Work (PoW) (2020) is probably the single most important process-based framework applicable in a UK context. Given its popularity and compelling graphic presentation by RIBA, readers can refer to both the Plan of Work template[45] and the comprehensive guide for the framework[46]. Compared to the previous version, the PoW (2020) integrates sustainability considerations more explicitly throughout the life cycle projects.[47] Other process frameworks are often overlayed with the RIBA PoW , such as the Construction Innovation Hub's Value Toolkit (2021).

The Construction Innovation Hub (2021) operationalises a holistic, cross-cutting definition of value by way of an integrated process that comprises key project stages, value definition, risk, client approach, measurement and evaluation, and role appointments (Figure 6).[48] The value components comprise natural, human, social and produced capital (more below).

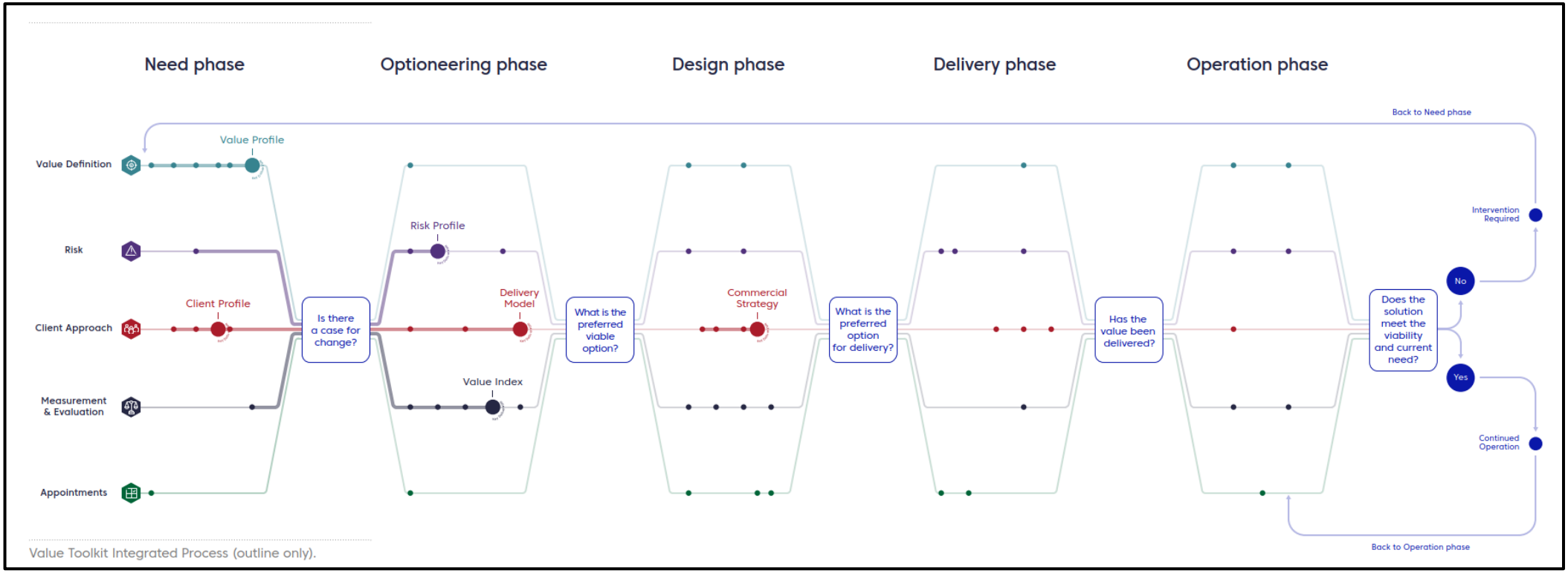
[45] The RIBA Plan of Work 2020 template (one-pager): [https://www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/2020RIBAPlanofWorktemplatepdf.pdf]

[46] The full overview to the RIBA Plan of Work 2020: [https://www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/2020RIBAPlanofWorkoverviewpdf.pdf]

[47] Read the article by Dale Sinclair (28 October 2019) to see what has changed in the RIBA Plan of Work 2020 since 2013: [https://www.ribaj.com/intelligence/updates-to-the-riba-plan-of-work-2019-dale-sinclair-gary-clark]

[48] The Construction Innovation Hub provides a detailed version of the integrated process here: [http://www.constructioninnovationhub.org.uk/value-toolkit]

Figure 6 - Value Toolkit Integrated Process outline (CIH, 2021, p. 12)



Considering the carbon impact of building development and retrofits, **the UKGBC net zero carbon buildings framework** (2019) prescribes five steps to manage carbon performance: 1) establish a net zero scope; 2) reduce construction impacts; 3) reduce operational energy use; 4) increase renewable energy supply; and 5) offset any remaining carbon by adopting a recognised offsetting framework and publicly disclosing offset amounts.

Some existing frameworks providing general though useful orientations for process-related project planning and management. One such framework is **the 'CEREB framework for successful retrofit programme design'**[49] developed at London South Bank University based on the analysis of retrofit schemes in the UK, USA and Canada. It comprises five pillars: 1) *programme design*, including assessing the market and establish partnerships; 2) *marketing and outreach* to engage homeowners; 3) *workforce engagement* to address skills gaps across the supply chain and upskilling; 4) securing *financial incentives* such as grants and/or loans, including how to combine them; 5) *continuous data collection and evaluation* for programme evaluation and iterative improvements. Gillich, Sunikka-Blank, and Ford (2018) indicate that a 2% budget investment on data and evaluation alone can ensure the rest of the investment can effectively leverage the intended goals of the programme. The framework also overlaps with and reinforces the recommendations in the 'Each Home Counts' review. Stakeholder engagement is also essential and covers all four pillars besides finance.

A 'fabric-first' approach to retrofits can also be conceived as process-based framework, beginning with improving the thermal performance of the building fabric, and ending with introducing or increasing renewable energy supply. The staging of a fabric first approach will necessarily consider financial opportunities and value proposition models that are available.

The Swedish **SIRen methodology** also provides an effective temporal framework for improved decision-making that can be used as a simplified version the RIBA Plan of Work (2020), and echoes with the Construction Innovation Hub's Value Toolkit (2021) (more above).

Definitions, targets and metrics

Net-zero and low-carbon

The UK Green Building Council (UKGBC) (2019) provides two standard definitions for net zero carbon buildings. The first, 'Net zero carbon – construction', refers to new buildings and major renovations:

> "When the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through the use of offsets or the next export of on-site renewable energy" (UKGBC, 2019, p. 18).

The second, "Net zero carbon – operational energy", refers to a building whilst in use:

> "When the amount of carbon emissions associated with a building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or offsite renewable energy sources, with any remaining carbon balance offset" (UKGBC, 2019, p. 20).

The second definition primarily applies to existing buildings, but operational energy should of course be considered at the design stage for new builds as well.

Beyond the UKGBC framework definition, there are multiple approaches to energy-efficiency in the affordable housing sector. This section provides various practical definitions, followed by scoping issues around what is included in 'net-zero' and 'nearly-zero' strategies. In particular, a rigid focus on

[49] CEREB is the Centre for Efficient and Renewable Energy in Buildings at London South Bank University: [https://www.lsbu.ac.uk/about-us/sustainability-at-lsbu/what-are-we-doing-now/cereb]

zero-carbon performance may divert attention from the wider environmental and community impacts caused by different renovation strategies.

Other standards adopt a 'systems' approach to carbon assessment. The ESG reporting standard provides an enhanced criteria (C16) that considers GHG emissions from owned and controlled sources (Scope 1), indirect emissions from the supplied energy (Scope 2) and indirect emissions from the rest of the value (i.e. supply) chain (Scope 3) (The Good Economy, 2020, p. 33). This is important as thorough ESG reporting can give access to significant bank investment for retrofits and energy efficient new development among social landlords. This criteria complements other criteria in the standard to help assess an organisation's efforts toward energy efficiency, positive community impact and sustainability as a whole. This strengthens the case for conducting carbon assessments as part of systemic approaches to retrofits, and therefore weakens the financial case for piecemeal and uncoordinated interventions toward net zero carbon.

Issues with EPC and SAP

Based on statistical analysis of a database of over 1100 building retrofits in Switzerland, Cozza et al. (2020) provide empirical evidence that EPC energy label and U-values of building envelopes are poor predictors of actual energy performance in practice. They argue energy savings estimations should be based on detailed descriptions of building envelopes and their components. Assessments should also be conducted by independent experts. Another study based on the analysis of EPC ratings for 1.6m UK homes indicates predicted errors may lead to homes being classified one full EPC rating above their actual performance (e.g. rated C instead of D, or even E instead of F, where an F rating would not quality a home for rental) (Crawley et al., 2019). The earlier, more modest FutureFit project monitored energy use for 150 retrofitted Affinity Sutton homes (now Clarion) in the period 2010-2013, indicating that actual energy savings were only half of those predicted using the standard EPC estimations.[50]

The Sustainable Renovation Guide (Morgan, 2018) favours a more balanced, integrated approach grounded in actual measurements of energy use. Estimations are particularly flawed in case of reduced data Standard Assessment Procedure (RdSAP), which is a streamlined and incidentally more common way of performing estimations of expected energy savings. The policy recommendation document by the Pebble Trust and partners 'Supporting sustainable renovation' (2021) builds on the guide to propose a range of policy tools and best practice to boost housing retrofits in Scotland. Indeed, the energy performance gap arising from EPC-based estimations, compounded with real thermal gaps arising from sub-standard installations, can greatly affect returns on investment (ROI) and trust in the retrofit industry at large (Technology Strategy Board, 2014).

Best practice for the evaluation of thermal performance points toward the need to collect sufficient real energy consumption data to cover even periods with extreme weather conditions, alongside more advanced simulations that integrate sensitivity and uncertainty analysis (Carratt, Kokogiannakis, & Daly, 2020). Current EPC-ratings

Another issue with EPC-based estimations of energy savings is the lack of consideration of tenant behaviour, including the 'rebound effect' that arising increased temperatures following retrofit interventions. Prior to a retrofit in a large social housing tower block in Portsmouth, Teli et al. (2016) monitored actual temperature and humidity levels as well as tenants' heating habits in 18 of the flats experiencing fuel poverty. They were able to derive occupant heating profiles which they used for dynamic thermal simulations. Overall, they found that estimated carbon saving were only half of those predicted through EPC-based averages. The findings also provide a more nuanced insight about the observed performance gap, arising from below-average energy consumption *prior* to the retrofit, and the subsequent low potential for real carbon savings. The study also recommends the use of monitoring over extended periods of time alongside studies about experiences of thermal comfort.

[50] See summaries of the FutureFit project (2010-2013) here: [http://www.clarionhg.com/media/1567/retrofit-3-download-our-verco-detailed-results-analysis-report.pdf]

Issues with carbon assessments

The integration of carbon assessment considerations throughout the whole life cycle of projects is a positive sign that greater consideration is being given to minimise environmental externalities (see for example RIBA, 2020 and UKGBC, 2019). However, there are significant methodological challenges when assessing and benchmarking the carbon performance of buildings (Dixit, 2017; Pan & Teng, 2021; Pomponi & Moncaster, 2018). In particular, these relate to scoping and calculation methods. The state of the art reveals that significant variations in carbon assessment studies may produce differences in results with up to two orders of magnitude. Therefore, carbon assessment methods need to be consistent and fully transparent to ensure their validity and reliability and enable to benchmark the performance of different buildings and retrofit options. A pending challenge is the selection of parameters and the many assumptions that underpin carbon assessments at large. At present, there is no consensual way to address these challenges. This is particularly problematic as carbon assessments have far-reaching implications for achieving 'true' net-zero targets in the built environment and for building collective trust and incentivising investment in net-zero pathways. So much so that Pomponi and Moncaster (2018) warn of the risk of a 'second wave' in performance gaps in the environmental assessment of buildings. On a positive note, the UK seems to be moving toward integrating embodied carbon at the design stage in building regulations (see UKGBC, 2019), as recommended by Pomponi and Moncaster (2018), although methodological consistency remains primordial.

Mission-led targets

The idea of missions-oriented strategies helps to break down high-level ambitions into discrete goals, key milestones and projects. Importantly, Kate Henderson, NHF chief executive, makes the case for a decarbonisation roadmap for housing associations to align with the orientations of the Sixth Carbon Budget.[51]

More generally, a missions-oriented approach can be adapted at any scale. Housing providers often have their own sustainability strategy and/or climate action plan, which can guide and harmonise home retrofits both at the individual project scale and across an organisation's building stock. For instance, the Hyde Pathway builds on extensive data collection and monitoring to formulate clear targets to align with net zero carbon policy orientations in the future.[52] Likewise, Sanctuary group recently published their Environment and Climate Change Strategy 2021 which provides a clear direction for their whole house retrofit programme while supporting ESG reporting.[53] Strategies such as these particularly help tackle UN Sustainable Development Goal 13 'Climate Action'.

A mission-led approach is useful for city-wide retrofits, within which specific retrofit projects might be embedded, as part of public-private partnerships. With the support of researchers at the UCL Institute for Innovation and Public Purpose, Greater Manchester has famously adopted a missions-oriented approach for its Five-year Environment Plan (2019-2024).[54] These comprise: 1) energy-efficient building retrofits with integrated low carbon heating and renewable energy generation and storage; 2) combined active travel network and green infrastructure corridors; 3) a resilient energy infrastructure; 4) a healthy natural environment; and 5) using waste for energy generation. A similar missions-oriented approach can be adapted to multi-organisational partnerships for portfolio retrofit innovation,

[51] See the article by NHF chief executive about the need for a decarbonisation roadmap [8 April 2021]: [https://www.housing.org.uk/news-and-blogs/blogs/kate-henderson/net-zero-2050-decarbonisation-roadmap-housing-associations/]

[52] See a brief description of the Hyde Pathway on the GFP website: [https://greenerfuturespartnership.co.uk/news/gfp-news/the-path-to-net-zero/]

[53] See Sanctuary Group's Environment and Climate Change statement here: [https://www.sanctuary-group.co.uk/sites/default/files/quick_media/sanctuary-environment-strategy-june-2021.pdf]

[54] See Greater Manchester's Five-Year Environment plan here: [https://www.greatermanchester-ca.gov.uk/media/1986/5-year-plan-branded_3.pdf]

in conjunction with wider urban and district-wide regeneration and retrofit programmes. See below for a diagrammatic illustration of GM's key goals in terms of 'a clean growth mission' approach: (GM, 2019, p 88).

Retrofit components

This section considers the state of the art in individual and all-in-one retrofit solutions found in the academic literature, industry guidance documents, and learnings from pilot/demonstrator and flagship projects across Europe. A cost appraisal of each retrofit component is beyond the scope of the report. A noteworthy cost analysis was performed to account for cost variation across the 115 home retrofits of the Retrofit for the Future programme, which takes into account variability in the choice of fabric interventions, choice of materials, and low carbon energy technology.[55]

Fabrics / building envelopes

Several industry reports provide evaluations of different types of fabric interventions and materials. One can cite the aforementioned cost analysis of retrofit options within the Retrofit for the Future programme. The Sustainable Renovation Guide provides a thorough overview and recommendations for all types of fabric interventions (Morgan, 2018).

Essentially, fabric interventions consist of solid wall insulation (either external or internal wall insulation), cavity wall insulation, roof insulation (including dormers) and floor/underfloor insulation. Most reviewed flagship demonstrators adopt EWI, while listed buildings and properties located in conservation areas typically require IWI for front/street-facing façades. Windows (double glazed or triple-glazed) and doors are also common as part of retrofit interventions. Robots such as Qbot can be used to install difficult to areas, such as for floor insulation. Demonstrator projects (e.g. Energiesprong, some EnerPHit) often use prefabricated panels with insulation for EWI or roof insulation. Other approaches may adopt 'plug-and-play' modular façades with integrated PV (e.g. the European RenoZeb approach - see Vavallo et al., 2019).

Bio-based/Biomass-based materials

A special mention concerns natural or 'bio-based' solutions that may display lower embodied carbon alongside good thermal performance compared to more conventional options. Life cycle and whole life cycle approaches to embodied carbon are central to the RIBA Sustainable Outcomes guide (2020) and the UKGBC Zero carbon framework definition (2019). L. Liu et al. (2017) review a range of biomass-based insulation materials and their applications for different parts of a buildings' fabric. For example, locally-extracted and locally-produced 'hempcrete' (i.e. hemp-line concrete) can be used for multiple fabric insulation solutions (including floors and walls) as can hemp-lime plaster.[56] Both can be used for EWI and IWI and are attractive, low-carbon solutions. Hemp-flax-lime composites can be used for wall insulation and prevent the growth of mould (Brzyski, Barnat-Hunek, Suchorab, & Łagód, 2017). Materials such as hemp and straw are fast-growing bio-based materials that can also function as carbon sinks in retrofit strategies if deployed at scale, as compared to wood-based materials that do not provide the same carbon storage potential (Agliata, Marino, Mollo, & Pariso, 2020; Pittau, Lumia, Heeren, Iannaccone, & Habert, 2019). In particular, these can be integrated as part of a circular construction economy and urban regeneration and revitalisation strategies (Torre, Cattaneo, Lenzi, & Zanelli, 2020). Current limitations for sustainable bio-based insulation and construction materials may largely be skills- and supply chain-related, rather than cost-related per se.

[55] See the post-completion cost analysis conducted by Sweett Group for TSB concerning 70 of the 115 retrofits within the Retrofit for the Future programme (2014): [https://www.ukgbc.org/wp-content/uploads/2018/10/Retrofit-for-the-Future-analysis-of-cost-data-report-2014.pdf]

[56] See for example a deep retrofit case study in County Dublin by hemp materials supplier Hempbuild: [https://www.hempbuild.ie/deep-hempcrete-retrofit-skerries-residence]

Notwithstanding, they are worth considering to future-proof both existing and new homes, for instance as part of a demonstrator innovation portfolio.

Low-carbon heat and electricity

Typical low-carbon heat and electricity microgeneration concerns air-source heat pumps, ground-source heat pumps (typically using bore-holes and supplied as community energy or district heating), PV panels with batteries for storage, solar collectors. MVAC contribute indirectly by minimising heat losses while regulating indoor air quality.

Where onsite production is not possible, contracting/procurement can favour 'green' power and heat supply. Some councils such as the London Borough of Camden have notably invested in decentralised energy networks (DEN), such as Combined Heat and Power plants (CHP), that can for example supply social housing.[57]

Ventilation

Mechanical ventilation with heat recovery (MVHR) improves indoor air quality through air ventilation while minimising heat losses and ensuring air tightness. Passivhaus standard.

MMC & prefabricated solutions

Modern methods of construction (MMC) typically refers to the offsite fabrication / prefabrication of building components. The MMC Working Group initiated by MHCLG provides a framework definition that covers different types of MMC: a range of five construction components that are built offsite or near the site of construction, supplemented by two site-based process improvement measures to minimise on-site assembly disruptions, for example through automation and labour reduction.[58] MMC are increasingly commonplace and will likely grow further. This could lead to significant economies of scale and leaner production across the construction industry. The Construction Playbook, which provides guidance for the procurement of public works and programmes, states: "Building on the presumption in favour of offsite construction, we are committed to creating a dynamic market for innovative technologies in the UK" (Cabinet Office, 2020, p. 20). Likewise, the NHF's Building Better Vision (2020) underscores the need for greater collaboration to deliver more homes through MMC . Projects that involve MMC both require and can strengthen greater collaboration between stakeholders, including advanced project coordination.

The grey literature for social housing demonstrators across Europe typically highlights the following combined benefits of MMC: lower construction costs, less construction waste (i.e. lean construction processes), less nuisance to neighbours and the community (e.g. traffic, noise and air pollution), and fewer inconveniences to occupants.[59] Likewise, Oakley (2018, p. 5) of WPI Economics reviews the benefits of offsite construction as: more reliable delivery, greater efficiency, improved and more consistent quality, improved safety and workforce satisfaction, reduced environmental impact, and increased support from local residents. In turn, upscaling offsite construction could lead to more jobs and improved skills provision outside of the Greater London region. A webinar hosted by the NHF in June 2020 also highlighted the critical importance of MMC for post-covid recovery.[60]

MMC solutions in retrofits typically come as packages. Mainly, these concern EWI and modular façade interventions, which can be complemented with roof insulation and on-site renewable energy

[57] See the description of the Somers Town Heat Network at Camden Council: [https://www.uk100.org/projects/knowledgehub/somers-town-energy]

[58] See the MHCLG MMC Working Group's framework definition and visual illustration of MMC: [https://www.cast-consultancy.com/wp-content/uploads/2019/03/MMC-I-Pad-base_GOVUK-FINAL_SECURE.pdf]

[59] These include the project descriptions for retrofit demonstrator programmes across Europe (Energiesprong, MORE-CONNECT, EnerPHit, and others) and in specific countries (e.g. renZero in Sweden).

[60] See the webinar 'Why modern methods of construction are essential for recovery post-covid (1 June 2020): [https://www.youtube.com/watch?app=desktop&v=e4RbnDvsuNg&feature=emb_title]

microgeneration. Interestingly, most identified MMC solutions are bespoke as per property. These include the EU-funded Energiesprong and the EnerPHit/outPHit approaches. MMCs favour integrated supply chains and the use of local contractors, often in partnership with large engineering companies and/or developers. For example, suppliers such as the French group Ecologgia-Techniwood provide natural, wood-based modular cladding panels together with insulation ('Panobloc'), as well as timber-framed new development of various sizes and typologies. In France, examples of EWI MMC include two social housing projects that adopt the European Passivhaus EnerPHit standard: 1) a joint retrofit-and-regeneration project concerning a tower block in the Luxembourg neighbourhood in Colmar as part of a long-term neighbourhood regeneration programme; 2) the retrofit of an apartment building in Colombes. The Energiesprong approach adopts all-in-one MMC packages measured as per property, including: façade EWI modules and cladding, and roof insulation (often with integrated PV and/or solar collectors). Entire modular homes can also be produced offsite.[61]

Through the combined economies of scale and scalability that they seek to leverage through MMC, a number of retrofit demonstrator programmes also aim at leveraging new **standards** for affordable 'zero-carbon' and 'near-zero' carbon retrofits (e.g. EnergieSprong, EnerPHit). The idea is not only to push for more stringent performance-based renovation norms within construction and procurement, but also to gain industry-recognised and policy-compliant certification. In fact, emerging retrofit approaches seem well ahead of existing government net zero carbon policy targets. Recent demonstrator programmes seem to be market-shaping, if not market-enabling. Such is already the case of the Passivhaus certification standard that underpins the EnerPHit and outPHit retrofit approaches, as it can be integrated with other landmark certification systems (e.g. BREEAM, WELL standard).

Smart technologies & BIM

Digital and 'smart' technologies in housing retrofits main consist of smart meters and various sensors that can monitor and control energy use, indoor air quality (e.g. moisture), air temperature, and humidity and temperature in different parts of the building fabric. Altogether, these measures can be produced in 'real-time' rather than estimated. Such measures are particularly useful to assess the effectiveness of retrofit interventions, for example humidity levels inside walls that previously suffered from water infiltration. For instance, an affordable, whole-building renovation of a student multi-apartment building in Tallinn (Estonia) used a wide range of sensing measures that enabled to optimise the refurbishment process from start to finish. During operations, the system enabled visualisation and steering of energy use, thermal performance, and general facilities management.[62]

Building Information Modelling (BIM) can also facilitate the life cycle management of projects from the determination of client information needs and technical design through to delivery and re-use.[63]The Construction Playbook recommends the use of BIM and Digital Twins among contracting authorities and suppliers, as these technologies "will help to improve the performance, sustainability and value for money of projects and programmes by providing data-driven insights that improve decision-making" (Cabinet Office, 2020, p. 20). However, based on ten interviews and surveys with senior professionals in social housing, Phillips and Foreman (2018) identify three main obstacles to the use of BIM for social housing retrofits: 1) *a lack of understanding* about how BIM operates; 2) *satisfaction* with current facilities management software; and 3) *no perceived need* for BIM. Opportunities lie in terms of being able to populate a BIM model iteratively as retrofit projects are completed, which could in the long run replace the legacy IT systems. Also, BIM providers could provide more bespoke

[61] See for example Beattie Passive's range of Passivhaus fully modular 1-3 bedroom homes: [https://beattiepassive.com/modular.php]

[62] See the summary and complete video for the EU-funded MORE-CONNECT demonstrator in Tallinn, a partnership between the Tallinn University of Technology and the university's student housing provider: [https://www.more-connect.eu/demonstration-project/pilot-homes-estonia/]

[63] The UK BIM Framework provides comprehensive guidance about technical standards: [https://www.ukbimframework.org/]

solutions that can easily be integrated with existing facilities management software. A study that investigated the renovation of 900 socially rented apartments in Sweden also revealed the need for greater data and software integration, providing support for a gradual rather than sudden adoption of BIM software and workflows (Koch & Larsen, 2018). Furthermore, extensive interaction with tenants was shown to be critical for the effective adoption of BIM and the collaborative retrofit process the technology entails. Investment in BIM may also be tied to wider renovation programmes. For instance, Camden Council procured a cloud-based 3D BIM model (Refurbify) to support the whole refurbishment process for Denton Towers in 2016.[64] This was associated with EWI at other properties on the same estate in 2015.[65]

As digital collaborative technologies for construction and renovation become more widespread across the industry, they could perhaps become more advantageous for housing associations to manage all types of properties. BIM is a core component for several retrofit demonstrator methodologies partnerships, such as the EU-funded RenoZEB (Vavallo et al., 2019).[66] BIM can also provide 4D models (i.e. 3D over time) to assess and test different retrofit options and minimise on-site interruptions through improved planning and logistics (Tzortzopoulos, Ma, Soliman Junior, & Koskela, 2019). Finally, BIM has been used in retrofitting all types of social housing properties, from single family, terraced houses (Tzortzopoulos et al., 2019) to multi-family apartment buildings (Koch & Larsen, 2018).

Green space and amenities

"This pandemic has made us rethink, in so many ways, how we live and how we want to live.

It has starkly reminded us of the importance of having a decent, safe and secure home with access to green spaces in which people can exercise, relax and unwind.

That is especially the case for social housing and the millions of people who call it home."

Minister for Housing Christopher Pincher's speech at the PlaceShapers' annual conference, 24 November 2020.67

The scientific literature abounds with studies about the health and ecological benefits of urban green space (Douglas, 2012). Urban ecology reveals the complementary environmental, economic, and human benefits and interdependencies of quality urban green space, which can directly shape people's health and life opportunities, through the provision of essential ecosystem services (Wu, 2014; Millenium Ecosystem Assessment, 2005), including children's play and social interactions (Laaksoharju et al., 2012). Therefore, access to green space presupposes equitable access. Conversely, a lack of access to greenspace, due to unequal distribution, is one among many signs of social inequalities in society (Haase et al., 2017). Introducing urban green space may also lead to gentrification and inequalities by contributing to increase property prices (Wolch, 2014). There also inherent tensions between urban density, limiting urban sprawl and equitable access to green space (Campbell, 1996), as exemplified by the 'green belt' conundrum across the UK as elsewhere. Green

[64] See the project description by the BIM supplier: [https://6c6f4dc3-8c27-47bd-adbc-71117f0fdf6b.filesusr.com/ugd/72b0d3_8477eff8e8104451a6564fe6a64e5860.pdf]

[65] Description of the EWI intervention at the Denton Estate in Camden Council in 2015: [https://www.uk.weber/facades/denton-estate-camden-north-london]

[66] See the description of the RenoZEB methodology supported by BIM, with real demonstrators in Estonia and Spain: [https://renozeb.eu/results/real-demo-cases.html]

[67] See the transcript of the speech here: [https://www.gov.uk/government/speeches/housing-ministers-speech-at-placeshapers-annual-conference]

space should therefore be inclusive. The National Model Design Code[68] by MHCLG (2020) also underscores the importance of green space for creating healthy places for everyone. Housing providers' contributions to biodiversity and ecology are also encouraged in ESG reporting (Enhanced criterion C20, but also C18). Non-profits such as Greenspace Scotland provide a wealth of resources, case studies and toolkits to help design, fund, and maintain all types of green space.[69]

Housing providers can be instrumental to improving the quality and availability of green space for residents, on estates as well as in the wider community. Studies have demonstrated the potential to integrate high-quality green space during social housing retrofit projects over blocks or at neighbourhood level, which can lead to both outdoor and thermal comfort by reducing urban heat islands, among other benefits (e.g. Pastore et al., 2013). Long-term regeneration at LB Hammersmith and Fullham featured the landmark retrofit of Edward Woods Estate, now topped with extensive resident consultations through the 'NOURISH' scheme to shape the design of green space creation and improvement at several locations around the estate. The scheme will also benefit flagship mixed-use development at White City.[70] New development also naturally lends itself to green space creation and enhancement. For instance, the flagship Gateshead Innovation Village should feature sustainable urban drainage systems (SuDS), alongside other green space functions, that will enhance quality of life at the site.[71] Historically, large open space between buildings, as well as providing ample exposure to sunlight and space for greenery on balconies, have proved popular at such sites as at the iconic Wohnpark Alt Erlaa in Vienna (Kilnarová and Wittmann, 2017).[72]

Urban gardening and agriculture can contribute to alleviating food poverty, environmental education, physical exercise and general wellbeing. Noteworthy community initiatives include the nation-wide Incredible Edible network, for instance at Brittany Point on the Ethereld Estate in Kennington (London Borough of Lambeth).[73] Groundwork London have also initiated 'community food growing hubs' with various partners that benefit social housing residents across London boroughs, including children.[74] More broadly, Rupprecht et al. (2015) identify a wide range of informal green space interventions that can be easily promoted at a variety of scales, including on disused land or in small vacant spaces, from street verges, lots and gaps between walls to microsites and brownfields. Biodiversity and green qualities can therefore be introduced, enhanced and nurtured in many ways.

[68] The National Model Design Code (MHCLG, 2020) aims to enable quality design in the built environment: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957205/National_Model_Design_Code.pdf]

[69] Greenspace Scotland is a leading organisation in the UK that promotes high quality green space: [https://www.greenspacescotland.org.uk/]

[70] See here for a description of the NOURISH scheme at Edward Woods Estate and White City: [https://www.groundwork.org.uk/projects/nourish/]. The following consultation document presents final design proposals that were shaped through earlier engagement with residents, which local residents can further comment on: [https://www.groundwork.org.uk/wp-content/uploads/2019/09/EWEi-Proposal-Options-spring-2021.pdf]

[71] See the following brief description of development at Gateshead Innovation Village: [https://constructingexcellence.org.uk/home-group-gateshead-innovation-village/]

[72] See a quick description of the design and popularity of the affordable tenancy flats at Wohnpark Alt Erlaa, built in 1985 by adopting principles of utilitarian happiness. The estate houses 9,000 people: [http://architectuul.com/architecture/wohnpark-alt-erlaa]

[73] Incredible Edible Lambeth: [https://www.incredibleediblelambeth.org/map/#location=1559]

[74] See the community food growing hubs created by Groundwork London: [https://www.groundwork.org.uk/projects/community-food-growing-hubs/]

Retrofit approaches

Whole-house retrofits either favour a deep, 'all-in-one' approach, or an incremental, 'step-wise' retrofit), the state of a property (including the calendar of scheduled upgrades), and tenant/customer engagement.

Fabric-first approach

A fabric-first approach aims at optimising the thermal performance of a property's fabric/building envelope prior to any investment in renewable energies. It is a logical and cost-effective way of reducing energy demand as a first step toward improving overall energy-efficiency in both whole-house or incremental retrofits. From the perspective of the UKGBC (2019) framework definition of net zero carbon in buildings, a fabric-first approach can be operationalised by following the prescribed five-step process: *scoping* the desired performance for construction and operation → *reducing the impacts of retrofit works* grounded in a whole life cycle approach → *reducing operational energy* through reduced demand, as underpinned by continuous monitoring → *integrating renewable energy* either through on-site microgeneration or through supplier → *offsetting* any remaining carbon, as last resort.

A fabric-first approach can be adopted as a special intervention or as part of scheduled upgrades of end-of-life assets. Tony Hill at Livv Housing Group explains how retrofit measures at the group's properties are conducted as replacements of assets at the end of their planned lifecycle, with a view to minimise cost increases in existing business plans.[75] The group's existing asset strategy seeks to deliver an EPC rating of D on all homes by 2025, and EPC C and above by 2030. The group's separate net zero strategy aims to strengthen these objectives.

Focusing on historic and traditional buildings in Scotland, Hay and colleagues (2013) at Changeworks investigate both partial and whole-house retrofits, including the u-values and costs of specific interventions for three main archetypes (sandstone cottage, tenement flat, and granite cottage).[76] Several of the investigated properties are let by social landlords (see the list of UK demonstrators for some case studies).

Deep

The state of the art on demonstrator projects indicates a deep approach is the default choice for whole-house retrofits. However, demonstrator projects are typically conducted in 'sheltered', semi-experimental conditions that benefit from special types of funding (e.g. EU innovation funding), skilled support (e.g. project coordination and 'activation' teams), business models and new supply chain integration. At present, deep retrofit demonstrators typically seem to rely on elaborate partnerships that include universities, consultancies, domain-specific contractors and/or innovation agencies (more below). Noteworthy deep retrofit programmes include Energiesprong, retrofits conducted as part of district-wide renovation in the landmark EU-funded Sinfonia and EU-GUGLE projects, and retrofits by ENGIE Zero and ENGIE Regeneration. These typically rely on offsite prefabrication (MMC) with shorter onsite interventions, which enable to avoid decanting of occupants.

Step by step

Incremental, or 'step-by-step', retrofits are less common in the literature about demonstrator programmes. Noteworthy examples include the Arbed Warm Homes scheme initiated by the Welsh government (IET & Nottingham Trent, 2020; Atkinson et al., 2015).

[75] See the blog entry by Livv Housing Group executive director of property on the Unlock Net Zero website: [https://www.unlocknetzero.co.uk/news/welcome-net-zero-as-an-opportunity-to-create-path-for-others-to-follow]

[76] See the report by Hay and colleagues 'Green Deal, ECO and traditional buildings' (2013): [https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=d3cc13e0-f84a-4c39-bfb4-a59400a9952d]

There appears to be two main types of step-by-step whole house retrofits. The EnerPHit approach delivers whole-house retrofits to Passivhaus standard is successive stages to make sure each step implements excellence in workmanship and building performance. Famous UK projects include Wilmcote House at Portsmouth City Council, Erneley Close at One Manchester (formerly Eastlands Homes), and Cedars Court in Glasgow at Queens Cross Housing Association. While not necessarily requiring decanting, long-drawn retrofit works can be trying for residents. Such retrofit approaches require very high installation quality, which may lead to project delays where unexpected structural issues and complications are discovered during the works (e.g. at Wilmcote House and Erneley Close).

Another step-by-step approach seems to follow existing financial plans and using associated property upgrade schedules as an opportunity to conduct (additional) energy-efficiency measures (see the approach by Livv Housing Group above). The most sensible, long-term approach is to begin with thorough fabric improvements. Lack of long-term planning in terms of future proofing to net zero targets runs the risk having to modify former interventions, which may actually prove more costly overall, without any guarantee of achieving net zero in the long run. If well planned, step-by-step energy-efficient retrofits may provide a sound financial alternative to deep retrofits that are more costly upfront.

More comparative, longitudinal research and industry-wide experimentation is required to thoroughly assess the pros and cons of deep vs incremental whole-house retrofits for similar property types, retrofit technologies and occupant behaviour profiles.

Targeted

Besides whole-house approaches, targeted energy-efficiency measures are also common. These can feature just one or a small number of interventions (e.g. fabric insulation, low-carbon heating). The Arbed scheme in Wales seems to have initially targeted a whole-house approach to worst-performing low-income homes, but ended up delivering more piecemeal retrofit measures to more homes, with many properties suffering from consequences of poor installation workmanship. An incremental approach may therefore only target a whole-house retrofit *during* the course of successive interventions, rather than from the outset. Depending on the state of a property, a whole-house approach may not be necessary or desirable at present, given the lack of market maturity and evolving opportunities government funding. Finally, some hard-to-treat and listed homes may never reach EPC Band C. A properly designed and executed targeted approach to energy efficiency can prove more appropriate, as per context (financial, technical, occupant profiles, etc).

Flagship demonstrators and programmes

Table Z lists a selection flagship demonstrators and programmes across the UK and Europe. These mostly concern social housing retrofits. Some redevelopments, regeneration and new builds are also included where these featured exemplar MMC/prefab construction methods, low-cost technology packages, business models, partnership arrangements and/or tenant engagement strategies.

The selective list provides an indication of the state of the art in energy efficient retrofits. Specific components of these projects are discussed in relevant parts of this report. The cited projects utilise whatever secondary information is publicly available. Importantly, the review of retrofit projects showed that project evaluation is inconsistent and unsystematic, thereby greatly limiting benchmarking across the sector as a whole.

GFP and UK demonstrators

Below is a visual summary of the information about the demonstrator projects provided by the GFP members (Figure 7, in two parts). Table 1 displays the list of GFP projects, while Table 2 provides a selection of noteworthy UK demonstrators for benchmarking purposes.

Landmark projects include the 115 home retrofits across 86 projects conducted as part of the Retrofit for the Future programme (2010-2014). Of these 26 were measured before and after, allowing a

comparison with SAP forecasts. The Retrofit for the Future projects can be found on the Low Energy Buildings database[77], which also features low-energy new builds and other projects conducted in more recent years. Except for exemplary cases that featured longer-term monitoring by researchers (e.g. two to three years post-retrofit), the project evaluations were largely project-bound, revealing potential gaps in long-term evaluation for effective benchmarking and assessment of individual retrofit strategies. Descriptions of the property retrofits were provided ‘as planned’ rather than post-retrofit. Post-programme insight can be found in the report by TSB (2014), although it is aggregated and therefore less granular.

[77] The Low Energy Building database was created as part of the Retrofit for the Future programme [https://www.lowenergybuildings.org.uk/]

Figure 7 - Overview of GFP demonstrators (July 2021)

GFP demonstrators overview

~28,520 homes (11 projects/schemes)
→ ~25,000 Sanctuary whole-house scheme
→ 2100 EWI by Home Group
Deep & step-by-step retrofits
Wide range of portfolio innovations

SAP rating

Targeted EPC band across all projects:
C or D

Standards

PAS 2035
PAS 2030 & Trustmark (contractors)
Energiesprong, Passivhaus

Main project goals

Alleviate fuel poverty
Reduce energy bills
Community energy
Treat damp & mould
Decarbonise the stock
Wider community benefits

→ Translating mission into action

Portfolio of demonstrator projects and schemes tests the state of the art across many areas, including

- *Technology*: smart sensors, renewable energy, energy-efficient heating, ventilation
- *Modern methods of construction*
- *Customer engagement*
- *Energy-efficiency standards*
- *'Fabric-first' approach, and 'worst-homes' first*
- *Translating net zero targets into deliverable projects*

Key lessons

- ✓ GFP projects demonstrate opportunity for portfolio, multi-organisational innovation
- ✓ Pooled investment & partnership wherever possible (e.g. urban regeneration, district retrofit, community energy)
- ✓ Projects goals are interdependent and generate co-benefits
- ✓ Multiple environmental and social benefits strengthen ESG reporting
- ✓ Make use of standards and frameworks where appropriate: Energiesprong, PAS 2035, Passivhaus, ESG reporting criteria
- ✓ Provide supportive customer support throughout: e.g. retrofit liaison officers
- ✓ Involve customers from design brief to 'in-use' evaluation
- ✓ Decanting not always necessary but consider compensation for disruption & delays
- ✓ Foster proactive sustainable lifestyles, sustainability champions & support community initiatives

Process

Retrofit as part of scheduled renewal
→ EWI by Home Group

New build
→ Gateshead Innov Village
→ Craigbank Passivhaus pilot

MMC & off-site prefab materials
→ Gateshead Innovation Village

Certification & standards
→ Passivhaus (Craigbank)
→ Energiesprong (Paington)
→ Trustmark (Swaffham Prior)
→ PAS 2035 & 2030 (Sanctuary scheme)

Tenant engagement

Define customer journey *with* customers
→ Abri projects | Biomass (Anchor Hanover) Warm Homes Fund & Gateshead Innovation Village (Home Group)

Foster energy champions among tenants
→ Warm Homes Fund

Whole neighbourhood approach
→ Energiesrpong pilots (Sanctuary)

Fabric interventions

EWI (as main intervention)
→ Group-wide (Home group)
→ Rosyth EWI (Home Scotland)

IWI (as main intervention)
→ Shipcote Terrace

CWI
→ National scheme (Sanctuary)

Fabric-first approach
→ Shipcote Terrace (Home Group)
→ Abri projects
→ National scheme (Sanctuary)

Loft / roof insulation (as main insulation)
→ Shipcote (Home Group) → Abri projects
→ National scheme (Sanctuary)
→ Energiesprong pilots (Sanctuary)

Historic, conservation
→ Shipcote

Landscaping, SUDs, recreation

→ Gateshead Innovation Village
→ Blacon Adventure Playground at Blaycon Estate =

Building technology

PV w/ storage → Gateshead innov Village (Home)
PV farm → Swaffham Prior (Sanctuary)

Ground-source heat pump
→ Swaffham Prior
→ Gateshead Innovation Village
→ Energiesprong pilots (Sanctuary)

Air-source heat pump and/or MVHR
→ Warm Homes Fund (Hyde & Sanctuary)
→ Swafham Prior
→ Gateshead Innovation Village
→ Energiesprong pilots (Sanctuary)

District & Community energy
→ Biomass at Goole, Cramlington, Leeds
→ Swaffham Prior

Thermal storage
→ Gateshead Innovation Village (Home group)

IOT / Smart sensors & meters
→ Froxfield, Bruton and Southampton
→ Warm Homes Fund (Hyde)
→ Sanctuary projects

Table 1 - List of GFP demonstrator projects, as per July 2021

Name of project	Timeframe	Description	Main aims	Funding & business model (BM)	Cost per property	Estimated savings
Swaffham Prior Village (CB25) **Sanctuary**	July 2020-Late 2021	Connecting 42 general needs properties to Heating Swaffham Prior (community-led) project: bore-hole GSHP, ASHP and PV farm. HVAC. Indoor air-quality sensors. Formerly heated by LPG.	• Alleviate fuel poverty • Decarbonise	• Up to £50k for wet heating system works • Heating Swaffham Prior funding: BEIS, Cambridgeshire CC, Cambridge & Peterborough Combined Authority • Reduction to tenants' fuel bills	~£1,200 (tbc)	• EPC band C • 47k tonnes CO2 saved over 40 years • carbon monitoring
Low SAP Whole House Retrofit Programme **Sanctuary**	April 2018 - 2020s	Whole house. 'worst-first' retrofits of 25,000 low SAP properties across stock nation-wide. PAS 2035 and 2030. Incl: Insulation, ASHPS, PV, smart controls & meters, building services, as per property need.	• Alleviate fuel poverty • Decarbonise	• Reduction to tenants' fuel bills	£8-13k	Bands F & G → C by 2020 E → C by 2025 Others → C by 2030
Loft and CW Insulation Programme **Sanctuary**	April 2018 - 2020s	Nationwide. Number of properties to be confirmed.	• Alleviate fuel poverty • Decarbonise	as above?	£1-3k	At least EPC Band C
Warm Homes Fund - Air Source Heat Pumps **Sanctuary**	April 2020 - March 2022	Upgrading ~600 off grid properties with air source heat pumps (ASHP)	• Decarbonise • Alleviate fuel poverty	• Warm Homes Fund • Reduction to tenants' fuel bills	£6-8k	Increase by 10-20 SAP points

ZEBCat 1 Paignton **Sanctuary**	April 2018-March2021	Deep Energiesprong retrofits of 8 flats: EWI, new cladding, GSHP, ASHP, PV	• Decarbonise • Alleviate fuel poverty	• Energiesprong model • European Regional Development Fund, domestic RHI (comfort plan)	~£37.5k	At least EPC Band B
ZEBCat 2 Paignton Coleridge Court **Sanctuary**	May2021-Spring 2023	Deep Energiesprong retrofits of 30 bungalows: EWI, new cladding, GSHP, ASHP, PV	• Decarbonise • Alleviate fuel poverty	• Energiesprong model • European Regional Development Fund, domestic RHI (comfort plan)	n/a	At least EPC Band B
Blacon Adventure Playground Net Zero Pilot (CH1) **Sanctuary**	April 2020-April 2021	Playground exemplar upgrade for recreation and education about climate change, serving Blacon Estate.	• Decarbonise • Use green energy	• Benefits to wider community • £100k playground upgrade • savings on fuel bills	n/a	Net zero targeted
Craigbank Passivhaus new build Pilot **Sanctuary**	May 2021-May 2022	Passivhaus new built of two properties to compare w/ similar properties in area, focus on tenant experience of fuel bills & usability. IWI, solar collectors, biodiversity measures.	• Decarbonise • Alleviate fuel poverty	• Reduction to tenants' fuel bills	n/a	• Active monitoring
LAD 1B - East Cambs **Sanctuary**	April2021-Oct 2021	Improvements to thermal comfort and performance at properties across the area Number of properties to be confirmed	• Alleviate fuel poverty • Decarbonise	• £5k GHG LAD 1B scheme matched by £2.5k from Sanctuary (per property) • Reduction of fuel bills	£7.5k	EPC Band C

LAD 2 - Leeds City **Sanctuary**	July 2021 - Dec 2021	Improvements to thermal comfort and performance at properties across the area. Piloting new approach to community involvement (whole neighbourhood approach). Number of properties to be confirmed	• Alleviate fuel poverty • Decarbonise	• £5k GHG LAD 1B scheme matched by £2.5k from Sanctuary (per property) • Reduction of fuel bills	£7.5k	EPC Band C
Rosyth, Fife - External Wall Insulation **Home Scotland**	March2013 - Jan 2014	Fabric first: EWI, new windows, and doors at 246 mid and end terrace properties	• Tackle damp • Thermal performance	• £2.3m	£9.3k	EPC Band D & improved wall performance 2.1 → 0.3W/m2/k
External Wall Insulation **Home Group**	2014-2017	EWI at 2,100 properties with SAP below 60 / scheduled w/ render renewals / w/ penetrating damp. Stock-wide across NE, North & Scotland.	• Alleviate fuel poverty • Reduce energy consumption • Treat damp	• Reduction to tenants' fuel bills	n/a	• £26 average saving per month
Shipcote Terrace Gateshead **Home Group**	Jan 2015	Retrofitting 22 'hard to treat' listed Victorian terraced houses: IWI at front and EWI at rear	• Tackle damp • Thermal performance • Reduce energy bills	• £192,500	£8.75k	EPC Band E → D and above
Gateshead Innovation Village **Home Group**	Jan 2018 - June 2019	New build of 41 houses on land owned by HG. Aim: test & monitor MMC (x16) and modular new build (x19) w/ traditional build (x6), and low carbon energy options: GSHP, ASHP,	• Test viability and performance of various construction methods ag. traditional build	• £7.1m	~£173k (new build)	• Monitor gap b/w predicted and CO2 emissions, including MMC

		Thermal Store (Sunamp). Also: SuDS, tenant support.				
Warm Homes Fund **Home Group**	2019 - 2021	Replacing electric storage heaters w/ air source heat pumps	• Alleviate fuel poverty • Decarbonise • Reduce energy bills	• £1.1m Warm Homes Fund • Seeking more properties to maximise available funding	£9.2k	• Fuel bill savings (tbc)
Summer Hill Bootle Full retrofit **Home Group**	2021 – 2022	Full fabric, low carbon technology, external wall insulation, A++ glazing, new doors, solar with battery storage, ASHP along with bespoke in home energy advice service and full system training for how to use the ASHP effectively.	Improve thermal comfort, indoor air quality and reduce space heating demand to reduce energy bills for customers	(tbc)	(tbc)	(tbc)
Oughterside and Abbeytown Allerdale Full retrofit **Home Group**	2022 – 2023	Full fabric, low carbon technology, external wall insulation, A++ glazing, new doors, solar with battery storage, ASHP along with bespoke in home energy advice service and full system training for how to use the ASHP effectively.	Improve thermal comfort, indoor air quality and reduce space heating demand to reduce energy bills for customers	(tbc)	(tbc)	(tbc)

Froxfield Pilot Petersfield (GU32) **Abri**	March2020 - April2021	Fabric first retrofit of 27 mid and end terrace houses based on carbon baseline. EWI, roof, floor, windows & doors, smart sensors & meters.	• Decarbonise • Reduce fuel bills • Define customer journey w/ customer	• Ensure robust supply chain for larger scale roll-outs in future projects • Onsite or supplied renewables to be considered later	n/a	EPC Band C or above
Eastfields, Bruton Pilot (BA10) **Abri**	March2020 - April2021	Fabric first retrofit of 20 mid and end terrace houses based on carbon baseline. EWI, roof, floor, windows & doors, smart sensors & meters.	• Decarbonise • Reduce fuel bills • Define customer journey w/ customer	• Ensure robust supply chain for larger scale roll-outs in future projects	n/a	EPC Band C or above
Southampton Pilot **Abri**	March2020 - April2021	Fabric first retrofit of 75mid and end terrace houses based on carbon baseline. EWI, roof, floor, windows & doors, smart sensors & meters.	• Decarbonise • Reduce fuel bills • Define customer journey w/ customer	• Ensure robust supply chain for larger scale roll-outs in future projects	n/a	EPC Band C or above
Warm Homes Fund Chichester **Hyde**	March2019 - July 2020	Installation of ASHP at 41 properties with low EPC (E-G), off gas grid, and having inefficient electric storage heaters. Some properties: Switchee for monitoring and optimal heating; new gas boilers.	• Alleviate fuel poverty • Reduce energy bills • Thermal performance	• Reduction to tenants' fuel bills • Future fabric improvements expected for properties w/ EPC Band D	n/a	EPC Band C: 31 properties D: 10 properties
Biomass district heating at Goole, Leeds & Cramlington **Anchor**	Spring 2020 - Jan 2021	Three biomass district installations at three locations serving total of 129 homes w/ electric heating. Also loft insulation.	• Use green energy • Reduce carbon emissions • Reduce fuel bills	• Reduction to tenants' fuel bills	n/a	• 90% carbon emissions reduction (Goole) • 40% fuel bill reduction (compared to electric)

Hebburn Investment Regeneration **Home Group**	2020- 2025	Investment regen to 211 general needs properties suffering from structural defects: fabric first, removal of timber floors & new insulated solid floors, new PV whilst new roof installed & connected to hot water cylinders, oversized pipework ready for air source.	• Alleviate fuel poverty in one of UKs most deprived communities re IMD scores • Decarbonise	• Home group Capital • Reduction to tenants' fuel bills	~£2,772 for renewables plus fabric first measures	• Improvements from EPC band D to Band B • CO2 saved • reduced customer fuel bills
Peter Street, Whitehaven, Move On Fund Investment Regeneration **Home Group**	2020-22	Investment regen to 2 blocks of flats in Peter Street, Whitehaven. Fabric first plus new PV roof installed & connected to hot water cylinders. 88 PV panels = 35kw system	• Alleviate fuel poverty in one of UKs most deprived communities re IMD scores • Decarbonise	• Home group capital + Move On Fund capital • Reduction to tenants' fuel bills	~£47,250 for PV plus fabric first measures	• Generating an output of 11,514 kWh of electricity per block ie 23,028kWh / year for both blocks • Peter Street as a whole saves approx. 8,050kg of carbon per year • The combined scheme (ie 2 blocks) saves £3,400 per year on electricity and hot water to help tackle fuel poverty

Table 2 - Selection of noteworthy UK demonstrator projects

Name of project(s)	Timeframe	Description	Funding & business model (BM)	Cost per property	Estimated savings
Clifton flats, first Energiesprong pilot in Sneinton - Nottingham City Homes	2017	Deep whole retrofits of 10 homes: 7 terraced houses + 3 bungalows. EWI, roof, PV, ground source heat pumps, HVAC, smart meters & sensors	Energiesprong market activation & structuration (EU ESDR DREeM funding)	£42,000* [bungalows] £58,000* [terraced houses] -- (tbc)	55-58% energy savings for both property types (considering fabric improvements only)
The Courts - Sneinton - Nottingham City Homes	2017-9	Whole house retrofits of 94 homes across 4 blocks of maisonettes. EWI and innovative Low Temperature District Heating	£1.5m REMOUBAN funding	~£16,000 per home	Up to £500/a savings in fuel bills per home (estimated)
Energiesprong upscaled demonstrators - Nottingham City Homes	2019-2022	Upscaling Energiesprong approach with 155 extra homes. EWI, roof, PV, ground source heat pumps, HVAC, smart meters & sensors.	£4.8m EU prolonged funding mix w/ match funding from ALMO, for total of £10m. Energiesprong BM.	£64,500 per home	Up to 70%, and exporting to 25% of PV electricity (March-Sept)
Destination Zero 2 - Bakersfield - Nottingham City Homes	March-Dec 2021	Whole house retrofits of 104 properties based on experience of Energiesprong demonstrators. EWI, underfloor & perimeter, windows & doors as needed. ASHP + PV w/ battery + heating → 'M&E in a box'	£3.6 m BEIS SHDF	£34.600 per home	£250/a/home ~50kWh/m2/yr considering fabric improvements
Lancaster West Estate regeneration - W11 - RB Kensington & Chelsea	2018-2022	Retrofit of 367 homes (7 blocks) + Energiesprong for 38 more homes (EWI, PV, ASHP). Part of resident-led estate regeneration after Grenfell tragedy (building & neighbourhood safety, communal space, bathrooms, kitchens).	£19m SHDF (BEIS) + £1.6m EU funding (Mustbe0) for Energiesprong. Also £57.9m for general upgrades.	SHDF: £51,800 per home Energiesprong: £42,100 per home	Energiesprong: Net zero approach
Wilmcote House EnerPHit retrofit - Portsmouth City Council	2014-2018	Retrofit of 111 homes across 3 interlinked 11-storey blocks of flats. EWI, triple glazing, MVHR First EnerPHit project in the UK.	£13m	£117,000 incl. all communal space, fixtures and fittings	Estimated 40% energy savings
Cedar Court EnerPHit retrofits Glasgow -	2016-2019	Fabric-first' retrofit of 314 homes (award-winning)	£13.3m-£16 m	£42,300-£51,000 per home (tbc)	Up to 80%

Queens Cross Housing Association					
Edward Woods Estate Green Deal & CESP LB Hammersmith and Fullham	2011-2014	Step by step cross tenure whole-house retrofit of 528 flats across three 24-storey tower blocks. EWI & cladding, CWI, roof, windows, PV, interior fixtures, and development of penthouses on top of tower blocks. Part of long-term, ongoing estate and neighbourhood regeneration incl. green space	£16.13 m Green Deal, GLA, CESP and other investments £12.2 m for the tower blocks? (tbc)	£21,500 (~750 flats) (tbc)	n/a
Ethelred Estate retrofit, Kennington Lambeth Living	2009-2010	Retrofitting 291 flats across three 18-23-storey tower blocks, as part of comprehensive neighbourhood uplift. EWI & cladding, roof, PV, CHP district heating.	£15 m tbc CHP w/ ESCO arrangement	£51,000 (tbc)	n/a
Cedars Road Estate Clapham, LB Lambeth	2015-2016	Fabric first retrofit of 370 maisonettes with EWI, roof, windows & building services. Part of council's five-year £490 m Lambeth Housing Standard programme	£3.5 m ECO - £4.2 m total? (tbc)	~£9,500 (tbc)	n/a
Enerley Close EnerPHit retrofit - One Manchester	2015	Retrofitting 32 social homes across two blocks of flats.	£3.1 m	£97,000 incl. landscaping, tenant gardens & public realm	Heating post-works: 21kWh/m2/a
Tower block retrofits at Oxford City Council	2016-2017 (end date tbc)	Retrofitting 348 flats across five tower blocks in different areas of the council, cross tenure with large majority of tenants: EWI & cladding, some PV, building services and fire safety upgrades	£20m for scheduled repairs and energy efficiency improvements. Part of regeneration investment in some areas (e.g. Blackbird Leys)	~ £57,471 incl. communal areas, cladding replacement etc.	na
Chilton retrofits by Tolent, Durham County Council	Q2 2021→	EWI and renewables for 500 fuel poor properties, part of energy efficiency programme for 1,000 homes. Some measures already implemented.	£5 m, mostly BEIS SHDF	~£10,000 (tbc)	n/a

Renfrewshire EnerPHit retrofit Renfrewshire Council	2020-2021 (~6 weeks on site)	Retrofitting 75 terraced houses to EnerPHit standards w/ EWI, roof & underfloor, triple-glazed windows, PV, and MMC	£4.5m of which £1.8m BEIS (Whole House Retrofit competition)	£60,000	Up to 90% Targeted EPC B
Borehamwood retrofit by Engie, Essex Clarion	2018	Deep retrofits of 3 semi-detached houses to ENGIE Zero (PAS 2035) standard (initially aiming for Energiesprong) w/ modular EWI, PV, Switchee.	n/a	n/a	EPC Band B confirmed
Maldon Energiesprong by ENGIE Regen, Essex	Dec 2018-July 2019	Deep retrofits of 5 semi-detached houses to Energiesprong standard: Modular façade and roof, underfloor, PV, ASHP, MVHR, MMC	£725,000	n/a	Targeted EPC Band A (up from D) (based on actual measures)
Sutton Energiesprong retrofits Sutton Housing Partnership	2021-2022	Retrofitting 100 homes to Energiesprong standard, with first eight pilots to be completed by summer 2021. Part of council's climate strategy.	Mix: BEIS, Mayor of London Energy Leap pilot, and Sutton Council	n/a	Net zero
RE:NEW (GLA one-stop-shop) Enfield Council	2018	District ground source heat pumps to 400 flats across 8 tower blocks, connected to 16 communal boreholes	• ECO & non-domestic renewable heat incentive (RHI) • RE:NEW itsel: 90% EU funded and 10% match by GLA	n/a	Estimated 30-50% savings in energy bills
RE:NEW (GLA one-stop-shop) Hackney Council	2014-2016	Replacing expensive electric heating with efficient communal gas boilers in 800 homes across 10 blocks	£1.7m ECO, £4.2 low-interest loan from London Energy Efficiency Fund (LEEF) & Hackney Council budget	£7,300 + proportion from Hackney Council investment	n/a

***Table Z Selection of demonstrator projects and programmes across** Europe*

Project name	Location	Description	Key learnings
Energiesprong	NL, DE, UK, FR,	Deep, performance-based retrofits to boost subsidy-free market, integrate supply chains & generate economies of scale	Need for integrated supply chain, improved coordination, craftmanship & engagement
EnerPHit Luxembourg redevelopment	Colmar, France	Social housing blocks of flats, part of long-term urban regeneration & redevelopment	District heating, heat recovery from grey water; MMC; decanting of 150 households – part of EU-funded wave of Passivhaus retrofits
EnerPHit social housing retrofit in Colombes	Greater Paris, France	Retrofitting two blocks of social housing to EnerPHit standards	MMC (EWI wood-based modular panels), no decanting - part of EU-funded wave of Passivhaus retrofits
SINFONIA project - district retrofit in Bolzano	Bolzano, Italy	Retrofitting several blocks of social housing using MMC, district heating, smart mobility & technology	High energy savings (formerly EPC G), demonstrates standard for Mediterranean climate and context. Significant red tape in Italy to fight corruption. Local research institute partners
SINFONIA project – Innsbruck	Innsbruck, Germany	Retrofit of affordable housing blocks to EnerPHit standard (EPC A), w/ MVHR, PV, solar collectors, heat pumps and district heating (biogas). Selection of monitored flats.	Tenants had to co-finance some of the measures at some properties. No decanting. Some disruptions to tenants. Estimated upgrades from EPC C to A. Local university partners.
EU-GUGLE Aachen retrofits	Aachen, Germany	Retrofitting social & very low-income homes (listed and modern); innovative district heating, PV, MVHR, language barriers	EU-funded, partnership with municipal utility and city, extensive involvement and communication with occupants, listed building regulations constrained efficiency measures
EU-GUGLE EU-wide programme	Europe & Turkey	Similar to SINFONIA – delivering district retrofits and smart city development	Vienna, Plovdiv, Gothenburg, Gaziantep, Sestao, Tampere, Milano, Bratislava, Aachen
MORE-CONNECT Pilots across Europe	Several EU countries	Deep pilot retrofits of a small range of properties using MMC and extensive monitoring and simulation	Partnership with universities, consultants and suppliers, EU-funded
RenoBuild	Sweden	Development of property assessment tool based on pilots and simulations for sustainable decision-making and retrofit project management	The methodology is free to use, and functions as a downloadable excel spreadsheet. The SIRen methodology is an extension of the RenoBuild project
RenoZeb – Bilbao, Durango & Võru	Spain & Estonia	Single deep retrofit pilots with integrated modular façades (MMC)	Also featured virtual simulation demonstrators across Europe

Customer engagement

Overview

This section discusses different approaches to tenant engagement: the multiple roles and identities which tenants may have; how tenants currently use, and feel about, energy use in their homes; aspects of behavioural change; and how they are involved both *before*, *during* and *after* property retrofits. Finally, it also considers wider opportunities for tenant engagement in terms of community engagement, community building, and sustainable lifestyles, which all have a part to play in the effective design, testing, implementation, evaluation and upscaling of different energy-efficient retrofit options.

What's in a name? From customer to stakeholder

The 'Guide to Tackling Stigma in Social Housing' by CIH and the *See the Person* committee underscores the need of "getting it right" in the way tenants are engaged, and of "making it together with the people who live in the homes they own and manage" (Davis, 2020, pp. 8, 20, respectively).[78] The report indicates that: "often the word *customer* is used to account for the range of relationships they have with people who live in their homes of all tenures and/ or receive other services from them (Davis, 2020, p. 8) [italics added]." Regarding social renters specifically, a tenant can simply be defined as: "A person who occupies land or property rented from a landlord"[79]. Importantly, customers 'occupy' many roles, identities and functions. In today's modern society, residents are at once users, householders, clients, consumers, community members, citizens and stakeholders. It may be difficult or even undesirable to separate the one from the other, including if one should turn stigma on its head, or envision innovative, collaborative ways of delivering mass retrofits.

Customers can possess first-hand expertise of the property's indoor and exterior environment, as well as the wider neighbourhood and community, even where inappropriate care and unsocial behaviour is observed. A tenant can also be an expert in any number of professional and non-remunerated activities, ranging from key personal life skills to education and participation in social groups. Social housing tenants may also become owners, which can lead to housing estates displaying mixed tenures, or even gentrification over time. In both the community and property sense, the 'value' of a tenant is also an asset, as well as a liability. In a real property sense, a tenant is the steward of the 'home'. Where many occupants live under a single roof, tenancy relationships are predictably complex, messy, unforeseeable, and potentially damaging for both people and property. As can be the relationship between households. Tenant attitudes, worldviews and behaviour are therefore highly contextual and relational.

Finally, the real 'value' of property lies in the eyes of the beholder: the financial value of the existing home and possible retrofit solutions may, or may not, reflect its perceived value by those who use it the most. The stakes are high for both individuals and society. These include: personal health and life chances, public health and economic productivity, quality homes and carbon neutrality, attractive properties and neighbourhoods… A tenant is therefore also a stakeholder. In sum, the way(s) one chooses to engage with tenants, and the ways in which tenants see themselves and landlords, will invariably affect the long-term quality, performance and value of retrofit interventions.

Tenant behaviour & thermal comfort

While tenants can have multiple roles, one can also identify patterns in tenant's occupancy behaviours. Properties are unique by virtue of their physical condition as well as occupancy-related trends. Therefore, it makes sense to monitor household behaviour in terms of energy use and care for the property alongside a property's technical performance before, during and after retrofit works. This

[78] See the report by the Chartered Institute of Housing and the See the Person committee (Davis, 2020): [https://seetheperson.org/wp-content/uploads/2020/09/Guide-to-tackling-stigma.pdf]

[79] Entry on lexico.com [https://www.lexico.com/definition/tenant]

can generate more granular insight about the interdependencies between the two, and how specific retrofit interventions perform in relation to these. Tenant heating behaviour is also intricately linked with experiences of thermal comfort as well as understandings of fuel poverty.

An important study by van den Brom, Meijer, and Visscher (2018) analyses over 1.4 million social rent households based on a database that reviews building characteristics and a theoretical energy consumption index. The study investigates performance gaps in the most conventional sense (i.e. comparing theoretical vs actual energy use), as well as performance gaps that may arise due to variations in behaviour across households. The study identifies 18 household types based on demographic variables (e.g. household composition, income, employment status). Interestingly, the study reveals that the households with the highest 10% actual gas consumption consume less gas as compared to the theoretical/predicted gas consumption! Single households consumed the least electricity per m².

Tenant engagement is central to the acceptance of renewable energy installations in social housing. Based on an international review of more than 60 studies published between 2000 and 2016, McCabe et al. (2018) identify lack of resident engagement and an unclear understanding of users as major obstacles to the successful adoption of renewable energy technology. The FutureFit research project by Affinity Sutton Group (now part of Clarion) than ran 2010-2013 retrofitted and monitored 150 homes. It also showed that tenant behaviour is unpredictable and yet essential to achieving significant energy savings using a fabric-first approach.[80]

Tenant behaviour is complex and circumstantial. Based on a representative attitudinal survey distributed to 2,000 residents in each of five European countries (a total of 10,000 respondents living in across the UK, Sweden, Germany, Italy, and Spain), Sovacool et al. (2021) indicate that relative satisfaction with current heating systems and habits in terms of thermal comfort can potentially act as obstacles to the adoption of more energy-efficient behaviour and low-carbon heating systems. Five key themes emerge from the data, which point to important areas to consider for resident engagement and awareness raising: 1) *literacy* (knowledge and awareness about heating systems and control); 2) *sustainability* (heating practices, including social dynamics and conflicts among multi-occupant households); 3) *temperature preferences* and experiences of thermal comfort; 4) *desirability of change* (behaviour, investment, and trust in experts and government providing advice); 5) *cultural trends* within countries. The vast majority of respondent reported having gas boilers, and as many as 90% declared having limited or no control over heating settings. Respondents were generally supportive of low-carbon heating systems, but did not necessarily envision behaviour change. Statistical analysis of the responses shows that, across countries (2021, 26):

> "*Respondents who pay a mortgage and house-owners are more willing to pay extra fees for a low-carbon energy system*, since they probably have a long-term vision, are concerned and care about the environment. As expected, they showed a better literacy with respect to the topic […]. *By contrast, respondents living in social housing – and, most probably, not charged for energy fees or maintenance costs – act less responsibly, for example by keeping the heating on the whole day or by wearing light clothes even in winter*. This is also partially true for tenants because they are typically less aware of the specificity of energy bills and paying fix maintenance costs does not provide a clear understanding about energy consumption." [italics added].

Based on interviews with 27 tenants in Sweden, Femenias, Knutsson, and Jonsdotter (2020) likewise report tenants' openness toward energy efficiency and retrofits. However, tenants were less willing to contribute personally and financially. The study indicates the need for a more effective approach to awareness raising about energy-saving behaviour and the value of retrofits. Another Swedish study investigates experiences of thermal comfort among 90 social tenants across 33 multi-apartment buildings. The respondents largely reported feeling cold several times a day in winter as they had little

[80] Report summaries of the FutureFit retrofit and longitudinal monitoring project can be found here: [http://www.clarionhg.com/news-research/clarion-research/our-retrofit-research-project/]

control over heating settings (93% of apartment buildings in 2014 were heated with district heating, and many with centralised heating controls in buildings) (Hagejärd, Dokter, Rahe, & Femenías, 2021).

Cultural factors can also influence occupant behaviour, whereby preferences and behaviour are interlinked**.** Specifically in the UK, Sovacool et al. (2021) report that common habits included the tendency to underheat homes regardless of income levels, which points to cultural trends in thermal comfort. At the same time, extreme behaviours were also common, such as heating all year long, as were conflicts between occupants about preferred temperatures. Almost three quarters of UK respondents also reported opening windows during the winter. Across countries, 40% of respondents reported heating far outside the 20-22 degrees range, from as high as 30 to as low as 2 degrees. In all, the findings highlight that the wide range of observed views and practices cannot be addressed with a 'one-size-fits-all' approach. Furthermore: "this complexity suggests that the decarbonisation of household heat is a *co-evolutionary* and *dynamic* process that transcends markets and infrastructures – *being both shaped by them but also shaping their diffusion*" (Sovacool et al., 2021, p. 27) [italics added]. Focusing on experiences of thermal comfort in a student high-rise building in Southampton, Amin (2018) reveals significant differences among long term and new UK residents, as due to mixed climatic backgrounds. Past experiences of both indoor and outdoor climate influence occupants' experiences of thermal comfort.

Occupants of older, 'hard-to-treat' homes may also develop personal moral identities and dynamic experiences of thermal comfort based on memory and culture (Roberts & Henwood, 2019). Particularly, in-depth interviews and ethnographic studies can reveal the experiential complexities of 'thermal comfort' which should be investigated alongside more technical assessments of 'thermal performance'. The experiential logic of thermal comfort may therefore diverge from its technical and technological counterparts: "Current thermal comfort practices are often shaped by past experiences as well as anticipated futures, and so, are not only relational but also constantly in flux. The logic that underlies the seeking of thermal comfort is therefore not one of maximization, as is the case with technical efficiency, but rather of having needs satisfied in a meaningful way, so as to live sufficiently well" (Roberts & Henwood, 2019, pp. 483-484). Narrative-rich input from occupant engagement can therefore reveal both preferences and capacities for adaptation that are critical for the adoption of any new technology or retrofit interventions, or lack thereof due to technical unfeasibility, for example in homes that will never hit the legislated net zero carbon mark (see also Bryson, 2021).

Another relevant study investigates occupants' use of digital heating controls in 100 smart home**s** located in Birmingham, Bridgend, Manchester and Newcastle (Sovacool, Osborn, Martiskainen, & Lipson, 2020). The study uses qualitative data from the Energy Systems Catapult's Living Laboratory. These findings also reveal a great diversity of behaviours and preferences among users. A key finding is that occupants valued thermal comfort more than the choice of actual energy supply. Respondents also had a more dynamic experience of thermal comfort, being led to discover the difference between air temperature and radiant heat.

Finally, an investigation of self-reported thermal comfort across all demographics, tenure and common property types, reveals eight broad sets of needs that comprise: *wellbeing* (health, comfort), *resources* (cost and waste), *ease of use* (control and convenience), and *relational dynamics* within households (harmony) and with guests (hospitality) (Mallaband and Lipson, 2020). Thermal comfort is therefore an inherently multi-dimensional phenomenon that covers socio-cultural, physical and technical components.

In all, the above highlights the need to embed policy and technical interventions in people's lived experiences, particularly their needs, sense of wellbeing and thermal comfort, and involve customers accordingly throughout the lifecycle of retrofit projects (Lane et al., 2014).

‘Engaging for greener futures’: towards best practice

> **“You can’t talk about how heating our homes helps meet the net-zero carbon target in isolation – you have to put it in a wider climate and sustainability context.”**
>
> **Participant at TPAS and PlaceShapers engagement project to collect social tenants’ views about net zero carbon (Bryson, 2021, p. 2).**

The state of the art reveals that tenant/customer engagement should be ‘deep’, consistent and systematic. The ‘depth’ of engagement relates to the ways in which tenants can act as stakeholders. This implies opportunities for significant participation and collaboration, as borrowed from the field of public participation in public policy making (see Nabatchi & Leighninger, 2015). Consistent engagement relates to the quote cited above: are customers adequately involved in the full life cycle of retrofit projects, from scoping and design to continuous feedback and continuous monitoring of energy use? How does one engage customers in net zero carbon retrofits when inconsistencies in carbon reduction such as poor recycling and use of plastic are still rampant (see Bryson, 2021)? Engagement that is both deep and consistent points to the need for *empowerment*.[81] How ‘empowered’ are customers to adopt sustainable lifestyles and adapt to improved living environment and thermal comfort? How does that compare with the building conditions and behaviour of households down the road, or to environmental conditions in the wider community? Furthermore, effective engagement is also systematic. It should be continuous and permanent, rather than project-based or issue-based. While it makes sense to group and target formal engagement activities about different themes to prevent engagement fatigue, it also makes sense to provide permanent channels for two-way communication, dialogue, support and general community building. Engaging about energy efficiency measures and net zero carbon roadmaps will likely also address structural issues that underpin customers’ experiences, as revealed by the English Housing Survey for 2019-2020. These include: overcrowding, feelings of anxiety, feelings of loneliness, rent arrears, and enduring concerns about fire safety.[82]

Partnering with researchers at universities can enable continuous engagement with tenants before, during and after retrofit works. For example, researchers at LSE supported Portsmouth City Council throughout the technically challenging deep retrofit of Wilmcote House. Researchers kept contact with 15 residents throughout the process and were able to report both distressing conditions of fuel poverty before the retrofit, and high levels of thermal comfort and resident satisfaction after the works had been completed. The interviews with tenants complemented the data collected through monitoring devices, showing that many tenants did not heat their homes to levels recommended by the World Health Organisation (ECD Architects, 2018).

Several avenues for innovative tenant engagement are available that can complement existing approaches. First, education about climate and environmental issues can support sustainable

[81] The issue of ‘empowerment’ is a perennial theme in the field of citizen participation, although the term itself may be inappropriate in a context of customer engagement - particularly if should be perceived as ‘jargon’ or ‘corporate bingo’ by residents – see Davis (2019, p. 20): [https://seetheperson.org/wp-content/uploads/2020/09/Guide-to-tackling-stigma.pdf]

[82] See an overview of the takeaways from the English Housing Survey for social renters by Dominic Brady on Inside Housing (13 July 2021): [https://www.insidehousing.co.uk/insight/the-english-housing-survey-five-key-takeaways-71529?utm_source=Ocean%20Media%20Group&utm_medium=email&utm_campaign=12530258_IH-ASSET-MANAGEMENT-16-7-2021-GR&dm_i=1HH2,7GKEQ,6F7RZG,UBJMR,1]

lifestyles and run parallel to school curriculum.[83] Likewise, greater climate literacy and related leadership skills could be embedded in existing job and social inclusion schemes at housing associations. Education and training also concerns internal staff. A stakeholder and resident engagement report by PlaceChangers and TPAS also suggests that all customer-facing staff at social housing organisations should be more knowledgeable about green technology. Liaison officers with professional community engagement skills should also be permanently available and could also be present with engineers and technical teams when handing refurbished property to tenants (Bryson, 2021).[84] Additionally, the implementation of deep retrofit projects can lead to the training of internal staff as PAS 2035 certified retrofit coordinators. For instance, a deep whole-house retrofit for Clarion by ENGIE Zero UK in Broehamwood (Essex) led to PAS 2035 accreditation for two officers at Clarion and ENGIE, which can help improve retrofit coordination and engagement in future projects.[85]

Tenant-led initiatives should also be supported as appropriate. Researchers at LSE engaged with social tenants and community representatives to identify some best practice in actions led by social tenants across a range of areas. These include community gardening, solidarity, housing scrutiny, and recreational activities. The report also provides recommendations for training, support for tenant-led community initiatives, and inclusivity. Importantly, the initiatives demonstrate wider community benefits and social value (Benton & Power, 2018).[86] Tenant-led community building could also strengthen ESG Reporting. Toward this end, noteworthy measures include the 'Successful Places grants' at Hyde Charitable Trust that foster community initiatives.[87] Likewise, a scheme at Queens Cross Housing Association in Glasgow has channelled funding for various community initiatives, such as community food growing, as well as other projects through participatory budgeting.[88]

Insight from flagship development can also shed about opportunities to foster sustainable lifestyles through conditioned spaces. A project within the E2B2 partnership (a programme of research-led retrofits in social and affordable rental housing) features collaboration between researchers at KTH (Stockholm) and Malmö City Homes (MKB) around the development of the 'Greenhouse' flagship building in the neighbourhood of Augestenborg. The building was designed to foster social interaction, urban gardening on the flat's balconies and shared ground-level spaces, active mobility, and also featured green roofs, rooftop greenhouse, PV, and smart sensors.[89] While retrofits provide fewer opportunities to induce sustainable lifestyles, inspiration from new development can be combined with existing innovative tenant engagement to initiate and support low-cost community initiatives, such as community gardening and food hubs.

Local communities will need to journey together on the rocky road to net zero carbon. The state of the art provides evidence that customers should also be engaged as environmental stewards, community members and leaders, consumers and citizens. Methodologically, a 'deep', consistent and systematic approach to customer engagement and literacy provides opportunities to existing tools and practices

[83] See Unlock Net Zero's blog entry about how climate education is critical to encouraging behaviour change and fostering sustainable lifestyles, even if difficult to implement in practice: [https://www.unlocknetzero.co.uk/skills/quality-climate-education-key-to-driving-net-zero-by-2050]

[84] See also the presentations by Peter Rickaby (The Retrofit Academy) and Emily Brabham (Nottingham City Homes) at the 'Retrofit for social housing summit': [https://www.youtube.com/watch?v=Nh0gnPjtQ-Y]

[85] See details of the Borehamwood whole-house retrofit by ENGIE: [https://www.engie.co.uk/about-us/references/borehamwood/]

[86] The report about tenant-led community initiatives can be found here: [[https://sticerd.lse.ac.uk/textonly/LSEhousing/Research/Tenants_in_Action/Tenants-in-Action.pdf]]

[87] 'Successful Places' grants and case studies of customer-led community initiatives at Hyde Group: https://www.hyde-housing.co.uk/corporate/our-social-purpose/successful-places/

[88] See the Queens Cross Connected scheme that supports community initiatives (May 2021): [https://www.qcha.org.uk/news/317-community-projects-benefit-from-new-queens-cross-scheme]

[89] A project summary can be found here (in English) and the full project end report with complete research findings by E2B2 here (in Swedish).

from best practice in public consultation and community engagement.[90] In terms of community value, greater collective participation and literacy among customers and staff can help tap into pooled resources such as knowledge, skills, creativity and continuous learning. Joint efforts are essential to adopting sustainable behaviour across projects, households, and organisations in social housing. A perennial source of inspiration and practical insight can be found in the civic and pedagogical work of American educator John Dewey, which includes an emphasis on both informed deliberation and deep exploration on the one hand, followed by creative problem-solving and active participation on the other (Hildreth, 2012). The capacity to sequence meaningful investigation, dialogue and ideation can ensure both critical reflection and pragmatic action in a simple, effective ways. It can also help integrate conflicts and differences among participants and viewpoints, rather than ignoring or bypassing them.

Inclusive governance is also a major component of both ESG reporting and community engagement. Inclusive governance can take many forms. For example, Rochdale Borough Housing (ALMO for Rochdale Borough Council) prides itself to be the first tenant- and employee-owned social housing provider, working on a basis of 'mutual membership' and extensive collaboration.[91] Inclusive governance is also about co-creation with residents. Following the Grenfell Tragedy, residents at Lancaster West Estate have been involved in resident-led regeneration with the new ALMO (W11 Lancaster West Neighbourhood Team). The collaborative design approach will deliver improved building safety, communal space upgrades, and energy-efficiency measures for 367 homes thanks to SHDF funding by BEIS, besides existing Mustbe0 EU funding for the retrofit of 38 homes to the Energiesprong standard. Among the GFP Partners, likewise, the 'fabric-first' retrofit projects by Abri have engaged residents in defining the customer journey and to identify opportunities, benefits and potential challenges.

More broadly, the 'Together with Tenants' plan by the National Housing Association itself has been revised thanks to extensive consultation input in 2019. Looking forward, customers can be involved in net zero carbon charters and strategies developed by individual housing associations and partnerships. Relevant tools and techniques include resident panels, and climate juries. An original technique developed by experienced facilitators at LSE is the Think Tank model, which is a type of action-orientated participatory workshop involving small groups in deliberation, sharing of experience and problem-solving. Each Think Tank event produces proposals for action plans to engage local authorities and leadership staff at housing organisations.[92] Resident panels can also provide scrutiny and valuable bottom-up recommendations about housing providers' energy efficient retrofit strategies, for example at Tower Hamlet Homes.[93] These measures, among others, can facilitate resident-led retrofit programmes whilst empowering end-users.

In turn, comprehensive engagement and participation can both support the design of and help implement sound business models for retrofit portfolio innovation. Inclusive governance and resident participation are both pre-conditions for and successful outcomes of inclusive retrofit and regeneration strategies. Only collective awareness and engagement can be expected to leverage deep retrofits on a systemic scale (Krizmane et al., 2016). This also requires bespoke skills and jobs on a large scale.

[90] See for example the state of the art report 'Engaging for the Future' by Commonplace (2020) which builds on the cumulative experience of having engaged millions of UK residents in local placemaking and town planning: [https://www.commonplace.is/ebook-engaging-for-the-future]

[91] See for example RBH's Annual Report to Members (2019-2020): [https://www.rbh.org.uk/media/1809/annual-report-to-members-2019-20.pdf]

[92] See the LSE Housing Plus Academy Think Tank model: [https://sticerd.lse.ac.uk/lsehousing/research/Housing-Plus-Academy/think-tank-model.asp]

[93] See the Scrutiny Review Action Plan 2019-2020 by Tower Hamlet Homes Residents' Panel, around the theme of retrofitting energy efficiency solutions: [https://www.towerhamletshomes.org.uk/uploads/assets/thh-retrofitting-energy-efficiency-solutions-final.pdf]

Skills and jobs

This section focuses of the provision of much-needed skills and jobs to help deliver on energy efficient housing retrofits more affordably and at scale. Critically, this concerns the whole housing sector, as well as the non-residential sector. Within the remit of housing associations is the opportunity to make use of existing employment and community building schemes to help train cohorts of builders, community champions and project coordinators. Both policy, industry and academic experts observe a massive skills gap and labour shortage in terms of construction workmanship and retrofit project coordination (e.g. Pebble Trust and partners, 2021; RIBA, 2020 'Greener Homes'; Palmer et al, 2018). A report by WPI Economics for Heathrow Airport indicates that off-site construction can produce much-needed jobs outside of dense metropolitan regions such as Greater London and the wider South-East of England (Oakley, 2018). Government policies to 'build back better' also aim to create new jobs and upskill the labour force to deliver greener buildings such as the Ten Point Plan for a Green Industrial Revolution by BEIS (2020, p. 20).

In Wales, inadequate levels of workmanship were observed for the first phases of the NEST and Arbed home renovation programmes in the period 2010-2015, which were aimed at low-income households and the worst-performing properties (Grey et al., 2015; Atkinson et al., 2015). The need for jobs and skills in the sector constitute one of the key aims of the NEST scheme going forward.[94]The London mayor's Innovation Partnership also aims to create 150,000 jobs over the next decade to deliver mass retrofits in social housing across the capital and the rest of the country.[95]

Business models, value and co-benefits

Overview

This section reviews key strategic value-generation options, which can also be coined 'pathways',[96] for the adoption of energy-efficiency renovation measures relevant to social housing. Different business models and value generation models are examined. Given the observed lack of predictability and consistency in policy-led funding, special attention is given to value generation models that rely only minimally on government subsidies.[97] The state of the art on the policy realm indicates a consistent public investment strategy and framework is still pending. Even as the UK government fine tunes its policy support of market innovation, analysists indicate public investment will necessarily be gradual as all homes cannot be retrofitted at the same time using public funding alone.

Value

> **'You buy it cheap, you buy it twice'**
> **Adage in the construction sector**

[94] See the 2019-2020 NEST annual report (Welsh government, 2020, p. 20): [https://nest.gov.wales/workspace/uploads/files/nest-annual-report-english-5f5b522fc5fc2.pdf]

[95] See the news release 'Mayor declares a 'retrofit revolution' to tackle the climate emergency'

on the Greater London website: https://www.london.gov.uk/press-releases/mayoral/mayor-declares-a-retrofit-revolution

[96] The notion of 'pathway' can help combine strategic/high-level goals with detailed actions underpinned by continuous tenant engagement. See for example the closed public consultation for Camden Council's Better Homes programme (2021-2025): [https://consultations.wearecamden.org/supporting-communities/better-homes/consult_view/].

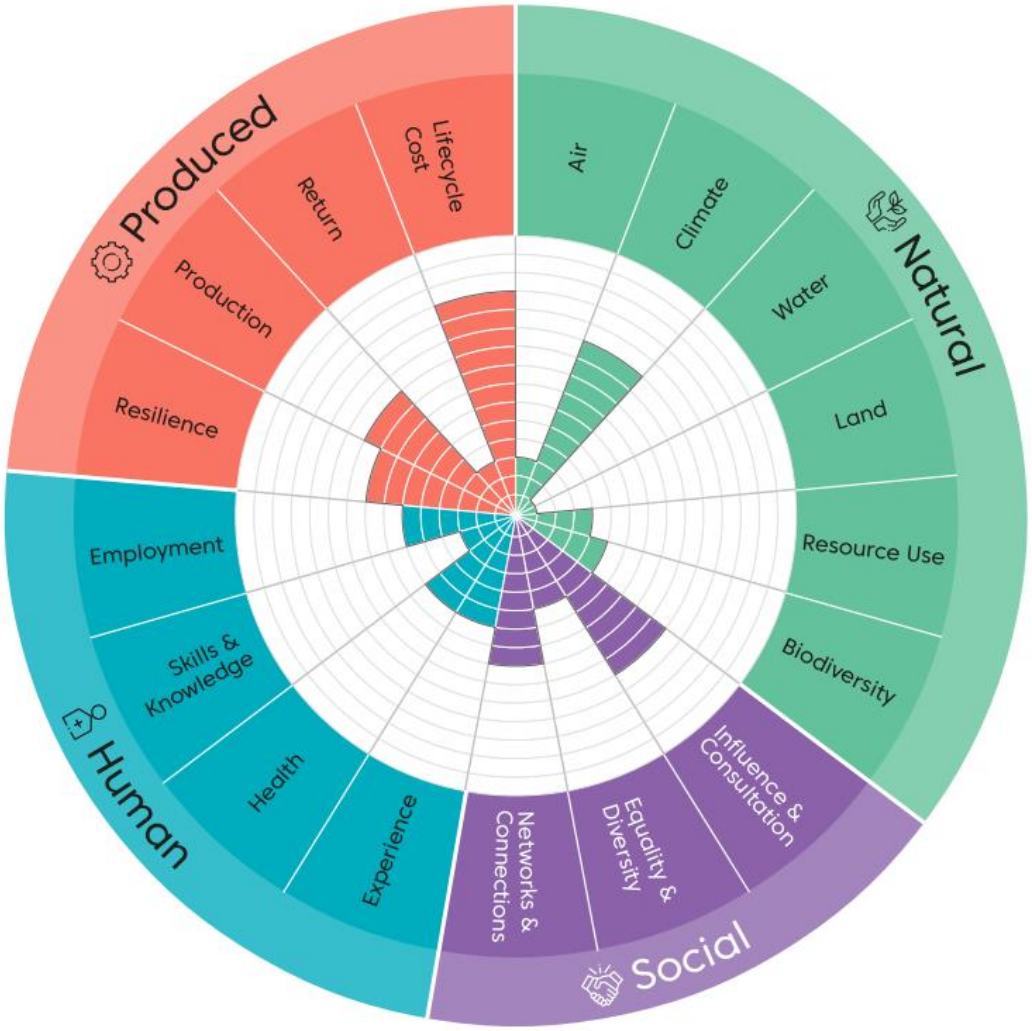
[97] This is also the focus of the flagship Energiesprong approach, although not yet a truly affordable approach as such for social housing.

Value is in the eyes of the beholder. As housing associations place great importance on their customer's well-being and life opportunities, alongside wider community well-being, they are arguably in a better position to adopt and advocate for comprehensive approaches to value generation than more profit-driven segments in the housing market.[98]

The Construction Innovation Hub's Value Toolkit (CIH, 2021) provides a comprehensive approach to value in the built environment. It articulates value in terms of produced, natural, social and human capital. Process wise, the Value Toolkit comprises *value definition*, *risk* (project Risk Profile with appropriate risk transfer and mitigation), *client approach* (delivery model and commercial strategy), *measurement and evaluation* (a specific Value Index built on a range of relevant indicators and methodologies), and *appointments* (i.e. delivery teams). Below is an example of a Value Profile that clearly communicates the formal priorities of a project or programme (Figure 8).

[98] In its synthetic description of the sector, the National Housing Federation (2019) emphasises the strong social value which housing associations provide: [https://www.housing.org.uk/globalassets/files/resource-files/political-engagement-toolkit/what-is-a-housing-association-2019-update.pdf]

Figure 8 - The Value Toolkit by the Construction Innovation Hub (2021)



Process-wise, the temporal operationalisation of Value Toolkit can easily align with the RIBA Plan of Work and other landmark processes. It streamlines process components into five phases: *Need* → *Optioneering* → *Design* → *Delivery* → *Operation*. Crucially, it locates value improvement and generation within the wider project context, beginning with a compelling 'mission' statement, and ending with a desirable 'project outcome'. To help measure project outcomes, the toolkit features a Metrics Library that provides complementary indicators and methodologies.

Of course, the cost of retrofit interventions remains key, particularly for housing associations as they manage properties below rental market value. A key cost assessment tool is Life Cycle Costing, which should be embedded into wider sustainability assessment methodologies (RICS, 2016). A performance-based approach such as outcomes-based procurement/tendering, beginning with a diagnostic phase that maps out thermal performance needs and actual energy uses, is typically recommended across the housing sector, such as cost-conscious cooperative housing in Sweden

Cost is relative rather than absolute: it depends on organisational budgets for specific types of interventions (e.g. scheduled upgrades or one-off/ad-hoc interventions), and scope (e.g. training and skills, maintenance costs required before retrofits). Therefore, cost also relates to costing and specific budget streams which may depend on individual projects, programmes or organisations. From a sustainability perspective, costing relates to the operationalisation of net-zero carbon targets in construction as well as operations Typically, this involves performing Life Cycle Costing and Whole

Life Costing to assess and monitor the overall environmental performance of building interventions, so as to minimise the externalisation of project-related environmental costs to society (more above). In sum, 'value' is much more than a financial tag, although cost is a primary decision-making factor. As economies of scale are leveraged in terms of material costs, supply chain integration and greater availability of skilled contractors and coordinators, 'cost' can be expected to go down, as initial evidence seems to suggest from the Energiesprong approach in the Netherlands.

Approaches such as EnerPHit (retrofits to near-Passivhaus standard), are designed as a flexible and 'affordable' mode of retrofitting on a mass scale. In particular, the EU-funded EuroPHit programme aimed at producing a range of pilot demonstrators to demonstrate the affordability of *step-by-step* energy-efficient retrofits.[99] A number of financial and investment planning guides resulted from the programme.[100] Some key insight includes making use of complex funding streams as appropriate, including: grant schemes, forgivable loans, commercial bank loans (some of which are increasingly 'green'), third party financing, credit to equipment suppliers and vendors, heating contract, and tradeable white certificates. The most popular seem to be grant schemes and commercial bank loans. The number one recommendation of the programme's final report is that (Doukov et al., 2016, p. 24):

> **"Combining energy efficiency projects in greater investment packages creates conditions for increasing the attractiveness of investments for the banks. The investment packages of energy efficiency projects pose significantly less risk of not meeting the expected minimum energy savings because the risk is distributed between multiple projects. It can be expected the reduced energy savings on one project to compensate with bigger savings on another."**

This insight fits with the observed 'greening' of finance through ESG reporting and the activities of the Green Finance institute, among others (more below).

Additionally, a recent report by Vivid Economics and Connected Places Catapult identifies a range of investment avenues to fund sustainability in UK residential sector, particularly the capacity to combine public, private and blended finance.[101] Government is expected to invest massively in energy-efficiency measures in the coming years, but by its very nature, public funding cannot come all at once.[102]

The average, 'optimal' cost for whole-house retrofits in housing seems to revolve around £20-25,000 per property, although this can vary widely according to property type, property condition, occupant behaviour/preferences, value chain integration, and so on. This figure has been suggested based on

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[99] See the final report for the EuroPHit programme here (2016): [https://europhit.eu/sites/europhit.eu/files/EuroPHit_D1.2_FinalPublishableReport_Optimized.pdf]

[100] See for example the EuroPHit 'Report on best practice financing models for energy efficient refurbishment': [https://europhit.eu/sites/europhit.eu/files/EuroPHit_D.4.3_ReportOnBestModels_EnEffect.pdf]

See also all the other EuroPHit resources related to finance: [https://europhit.eu/finance]

[101] See the report 'Financing innovation and transformation in the UK residential built environment sector' by Connected Places Catapult and Vivid Economics (2021): [https://cp.catapult.org.uk/wp-content/uploads/2021/03/CPC-Vivid-Economics-2021-Financing-Innovation-in-the-UK-Residential-Built-Environment-Sector.pdf]

[102] See the insight by Kate Duffy (senior advisor at BEIS) at the 'Retrofit for social housing summit' hosted by the Retrofit Academy 25 March 2021: [view at 1:10:00] [https://www.youtube.com/watch?v=Nh0gnPjtQ-Y].

insight from the landmark 'Retrofit for the Future' programme (2010-2014),[103] and a recent survey by Inside Housing (November 2020),[104] This estimated property retrofit cost does not seem to take into account costs related to upskilling and project management.

Social Value

The Social Value Toolkit by the RIBA and the University of Reading (2020) addresses social value in the built environment as: 1) *jobs and apprenticeships*; 2) *wellbeing*; 3) *participatory design*; 4) *learning from construction processes*; 5) using *locally-sourced construction materials*. The toolkit suggests the use of various methods, such as the BUS methodology Occupant Satisfaction Survey,[105] or Social Return on Investment (SROI)[106], which can inform both the design and improve the operations of projects. Social value can be mapped at a variety of spatial scales, such as the neighbourhood or even city level. SROI methods can be integrated during Post Occupancy Evaluations. The Social Value Toolkit provides an interview template framed around positive emotions about a building or neighbourhood, perceptions of social connection, freedom and flexibility, and participation. The HACT website also hosts the UK Social Value Bank, which provides a range of practical tools to measure and calculate social value.[107] HACT also provides a roadmap for social value in social housing,[108] and leads a bespoke Taskforce since 2020.

[103] See the insight shared by Peter Rickaby at a Retrofit Academy webinar about social housing retrofits: [See also the presentations by Peter Rickaby (The Retrofit Academy) and Emily Brabham (Nottingham City Homes) at the 'Retrofit for social housing summit': [https://www.youtube.com/watch?v=Nh0gnPjtQ-Y]]

[104] See the article by Lucie Heath (23 November 2020) in Inside Housing: [https://www.insidehousing.co.uk/insight/insight/the-cost-of-net-zero-social-landlords-decarbonisation-plans-revealed-68497]

[105] https://busmethodology.org.uk/

[106] Originating from the US, In the UK, SROIs have been operationalised in the UK by organisations the New Economics Foundation and Social Value UK. See for example the NEF's toolkit produced in 2007 [https://neweconomics.org/uploads/files/cf0968d3256d6bffcc_cim6bsty5.pdf] and Social Value UK's range of tools as per purpose/principle [https://socialvalueuk.org/resources/tools-by-principle/]

[107] HACT Social Value bank: [https://www.hact.org.uk/uk-social-value-bank]

[108] HACT_SV_Roadmap.pdf: [https://hact.org.uk/sites/default/files/HACT_SV_Roadmap.pdf]

Figure 9 - HACT roadmap for social value in social housing (HACT, 2020, p. 4)

The WELL Community Standard is a well-established certification framework to assess community well-being.[109] It goes beyond single buildings to consider wider community and neighbourhood environmental quality. It is structured around 10 guiding concepts: air and water quality, nourishment, light, movement, thermal comfort, sound, materials, 'mind' (mental and physical health), community, and innovations. In particular, each concept addresses interdependencies with the other concepts (e.g. through restorative green and blue spaces). The identified environmental interdependencies further exemplify the need for and help operationalise comprehensive approaches to sustainability in the built environment. The standard can be integrated with other frameworks reviewed in the report. At estate and neighbourhood levels, perceptions and uses of places can be assessed with methods such as 'sociotope mapping' and 'emotional mapping'. These can rely on a combination of community

[109] The WELL Community Standard: [https://v2.wellcertified.com/community/en/overview]

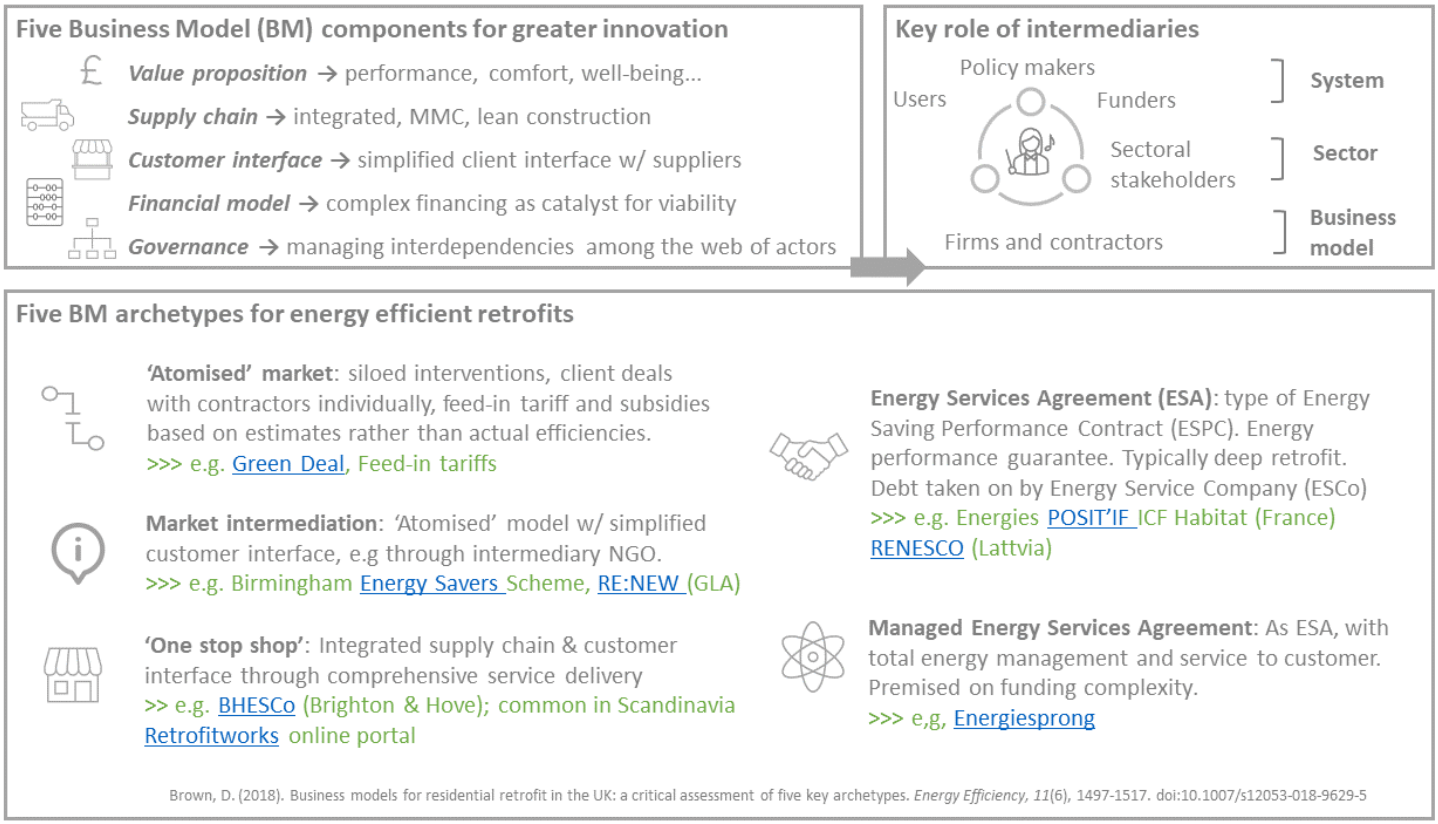
engagement methods, expert observation and spatial analysis (Babelon, 2015; Pánek, 2018; Ståhle, 2006).[110] Social value overlaps strongly with tenant engagement.

An extension of social value and wider community benefits in assessing retrofits is the concept of 'urban infrastructure' (Ince & Marvin, 2019). Urban infrastructure denotes the long-term socio-technical networks which retrofit schemes provide at the local level. This comprises local value chain integration, environmental performance as well as social equity measures. In short, retrofits delivered at scale across neighbourhoods, districts and cities have the potential to yield long-term shared benefits for the wider community and build capacity for a sustained carbon transition.

Business models for retrofit innovation

Based on a review of a wide range of housing retrofit programmes in the UK and Europe, Brown (2018) identifies five key business model archetypes. These are summarised in Figure 10.

Figure 10- Overview of current business model archetypes for housing retrofits in the UK. Adapted from Brown (2018).



Brown (2018) builds on former literature to highlight 5 key business model components to stimulate innovation. He then exemplifies how the five business model archetypes engage with these five key components. The atomised market model denotes the situation where a client has to manage retrofit projects entirely, often with poor supply chain integration, and energy savings based on estimations rather than real measurements. The market intermediation model essentially delegates the process to an agent that performs many these tasks on behalf of the client, or guides the client through these.

[110] Participatory mapping can help understand how users perceive public space. Examples from Czech Republic by Pánek (2018): [https://cartographicperspectives.org/index.php/journal/article/view/1419/1620]. Engagement tools such as Commonplace have been used to engage tenants in estate redevelopments: [https://www.commonplace.is/customer-stories/combining-offline-and-online-engagement-for-northwold-estate-redevelopment].

Currently, retrofit innovation seems to place primarily at 'One-stop shops', Energy Services Agreements (ESAs), and Managed Energy Services Agreements (MESAs). One-stop-shops are essentially a single customer-facing platform or intermediary that considerably simplifies the customer journey for property retrofits into a single bundle of services. One-stop-shops can be useful for both local authorities and housing providers or individual homeowners. Noteworthy examples in the UK include RetrofitWorks[111] based in the Brighton and Hove area, but active over the whole country, and Arbed am Byth, which has been responsible for serving as simple point of contact for retrofit services as part of the Welsh Government's Warm Homes Scheme.[112]

Focusing on the Energiesprong project,[113] Brown, Kivimaa, and Sorrell (2019) identify that intermediary project coordinators (in this instance the Energiesprong market development team) provide an essential role in *activating* projects, *brokering* in terms of raising resources and advocacy (among users, policymakers and funders), *facilitation* among all involved parties, and *configuring* business models locally at firm level. The greater the level of integration and coordination across the five business model components, the greater the potential to leverage innovation demonstrator projects and upscale successful approaches.

The final report for the Horizon 2020 INNOVATE project by the European Association of Cities in Energy Transition ('Energy Cities') also identifies four types of one-stop-shops (Cicmanova, Eisermann, & Maraquin, 2020).

Green finance

Besides the business models discussed above, bank finance may provide a promising avenue for funding in the absence of government funding consistency. The emerging opportunities for green finance in home retrofits can provide both direct investment and indirect sector-wide benefits for housing associations. The Green Finance Institute created the Coalition for the Energy Efficiency of Buildings (CEEB) "to stimulate action across the finance sector to support the decarbonisation of our homes", notably through the '"the co-design and launch of viable and impactful financial 'demonstrators' that provide the catalyst for further financial innovation at scale" (Green Finance Institute, 2020). Their report entitled 'Financing energy efficient buildings: The path to retrofit at scale' highlights fruitful avenues for joint investment in retrofitting both social and private housing by way of 21 scalable 'demonstrator projects'. The projects relate to *data and enabling frameworks* (e.g. TrustMark 'Call to Action' platform, and real-time metered energy savings), *tenancy agreements* (e.g. affordable rent standard definition covering both rent and energy bills), *lending products* (e.g. leaseholder financing to encourage multi-property renovations), *saving and investment products* (e.g. long-term retail investment in energy efficient properties), *energy service products* (e.g. Comfort as a Service, insurance-backed Comfort Plans for early adopters of deep retrofits, MEES compliant funding), and *government guaranteed financing* (i.e. support for large-scale, cross-tenure retrofits through upscaled supply chains and economies of scale). In all, the combined demonstrators aim to leverage 'systemic change' to tackle the climate challenge while supporting the 'Build Back Better' strategy of the UK government. The CEEB also provides insight about ways to improve 'green mortgages' with a view to refurbish existing homes in the private sector, in complement to sliding Stamp duties based on EPC ratings and extending Minimum energy efficiency standards (MEES) to the sale of owner-occupied homes.

Likewise, a report by Vivid Economics and Connected Places Catapult (2021)[114] highlights that groups such as NatWest and Nationwide are looking to expand their range of green products and seek to decarbonise their investment portfolio, with local authorities and housing associations as clients. Business models attractive to green finance including performance-based contracts such as Heat as a

[111] RetrofitWorks' website: [https://retrofitworks.co.uk/schemes/schemes-duplicate-1/]

[112] Arbed am Byth's website: [https://arbedambyth.wales/eng/home.html]

[113] See the Energiesprong UK website: [https://energiesprong.uk]

[114] Report by Vivid Economics and CPC (2021): [https://cp.catapult.org.uk/wp-content/uploads/2021/03/CPC-Vivid-Economics-2021-Financing-Innovation-in-the-UK-Residential-Built-Environment-Sector.pdf]

Service (HaaS) and Energy as a Service (EaaS), and one-stop-shops like RetrofitWorks and CurveBlcok that provide solution packages that combine technical, financial and delivery services. The report envisions a progressive growth in green, blended financing and investment across time, namely: a period of innovation until 2025, growth during 2025-2030, and maturity achieved in 2030-40, featuring widespread use of sustainability linked bonds, sustainable real estate investment trusts (REITs) and green structured products.

Environmental, Social and Governance (ESG) Reporting is a means of delivering standardised financial investment-grade criteria across the social housing sector (The Good Economy, 2020). The criteria comprise both 'core' (mandatory) and 'enhanced' criteria to enable all social and affordable housing landlords to adopt the reporting from where they currently stand. The reporting standard aims to move capital investment up from simply considering 'responsible' criteria to leverage greater 'sustainability' and 'impact' more directly and proactively. For instance, enhanced environmental criteria include a life cycle, systems approach to operational and embodied carbon, including across the whole value chain. Likewise, in their report 'Financing climate action with positive social impact,' Robins and colleagues (2020) highlight that UK finance can go beyond carbon considerations to embed strong inclusiveness criteria at the heart of investment, and thereby leverage a 'just transition' at scale.[115] As it is still an emerging practice, ESG reporting may take a couple of annual rounds of disclosures to streamline for housing associations, as highlighted by the Chief Financial Officer of Optivo. Additionally, there might be challenges around supplying comparable metrics for the ESG criteria across the social housing sector as a whole, as expected by analysts. Finally, effective ESG reporting requires intra-organisational collaboration across departments.[116]

The Pan-European Sustainable Housing Label developed by Ritterwald is designed to help affordable housing providers tap into corporate finance.[117] In due course, PAS 2035 and Energiesprong have the potential to be integrated in similar certification models to help attract mass investment. The push for quality reporting to stimulate investment from the financial sector is also supported at the EU level through the BuildUp project. The QualitEE consortium aims to bring together contractors, suppliers, public and private owners, financial institutions and investors, certification bodies and national organisations to devise quality assessment criteria and assurance schemes to facilitate energy efficiency measures.[118] In essence, this would entail an improved form of EPC-based rating. In parallel to QualitEE, the U-Cert project looks at ways to improve the certification of energy performance in buildings through user-centred design, taking ISO 52000-1 as the point of departure.[119]

Legal considerations

Legal considerations primarily concern the extra care in considering leaseholder clauses in cross tenure schemes. They also concern meeting national net zero carbon targets.

In a UK context, the management and coordination of mixed tenure schemes requires extra care with regards to reasonable charging of customers for expected building works. A contentious legal precedent considers the retrofitting of five tower blocks at Oxford City Council at Blackbird Leys and other neighbourhoods. A minority of occupants were leaseholders who had exercised the right to buy,

[115] See the report by Robins and colleagues (2020) at the LSE and the University of Leeds: [https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2020/07/Financing-climate-action-with-positive-social-impact_How-banking-can-support-a-just-transition-in-the-UK-1.pdf]

[116] See the account by Sarah Smith (Chief Financial Officer at Optivo) (14 July 2021): [https://www.housing.org.uk/news-and-blogs/blogs/sarah-smith/environmental-social-and-governance-reporting--our-experiences/]

[117] See a brief description of recent European Sustainable Housing Label here: [http://www.sustainable-housing.eu/#certification]

[118] See details of the QualitEE project here: [https://qualitee.eu/]

[119] See details of the U-Cert project here: [https://u-certproject.eu/proceedings/epcertificates-people/]

many of whom had then rented to other tenants. In 2017, Oxford City Council had to reduce bills initially costed at nearly £50,000 per leaseholder to about £4,000 for the cost of building works, as substantial property improvement costs could be not passed as maintenance fees.[120] The case highlights the socio-technical complexity of funding and managing cross-tenure schemes for energy-efficient retrofits by cost-conscious housing providers (Bright et al., 2019). Such legal considerations require extensive communication and customer engagement, as well as the capacity to identify multiple funding streams. At Nottingham City Homes, the flagship Energiesprong retrofit of the Clifton flats famously left some leasehold properties untouched.[121] Emily Brabham, Head of sustainable energy at NCH and director of Energiesprong UK, shares that cross tenure adds significant complexity to logistics and programming of interventions, including blended funding streams. These require different approaches for customer engagement, marketing and property assessments which make scoping a difficult exercise. At the same, the reaped benefits can be larger and enable wider regeneration efforts than single tenure schemes.

National net zero carbon targets are legally binding and therefore hinge on the participation of all stakeholders in society. The Green Futures Partnership provides an exemplar opportunity for portfolio retrofit innovation toward that end, as does each members' organisational climate strategies and ESG reporting.

Partnerships & portfolio innovation

Innovation partnerships in social housing and multifamily apartment buildings often comprise housing organisations, universities, industry (both large developers and SME contractors and consultancies), and/or innovation agencies (e.g. at EU level). The state of the art in retrofit pilots and demonstrator projects across Europe indicates the growth in partnerships to design, test and upscale low-cost approaches to retrofitting the homes that need it the most (i.e. occupants on low-income and/or homes with sub-standard performance regarding energy use, fuel poverty and health & safety).

In a landmark study about innovation in manufacturing, Faems, Van Looy, and Debackere (2005, p. 247) make the case for "a *portfolio of different, though complementary, interorganizational arrangements* for achieving innovation outcomes. To the extent that firms strive for multiple innovation outcomes, their innovation strategy might entail an appropriately balanced set of interorganizational collaborative arrangements" [italics added]. The current demonstrators for the Greener Futures Partnership indeed display a wide range of projects characterised by different scope and scale, objectives, housing typologies and fabrics, retrofit interventions and technologies, range of partners, funding streams, monitoring strategies, and approaches to tenant engagement. As such, the GFP can become a case in point for multi-organisational portfolio innovation. The rest of the section considers projects from the state of the art as well as the GFP demonstrator projects.

University partners

Common innovation partners include universities. Collaboration with universities was found across the majority of identified social housing retrofit demonstrator programmes in the UK and across Europe. Depending on the agreed research focus, the added-value of partnering with researchers is threefold: 1) opportunities for the *collaborative design and simulation* of different energy efficiency interventions; 2) opportunities for *extensive data collection* about energy consumption and occupant behaviour; and 3) opportunities for *participatory project evaluation and occupant engagement* throughout the lifecycle of retrofit interventions, including comprehensive post-occupancy evaluation, customer satisfaction assessments and longitudinal studies. Below are noteworthy examples.

[120] For a brief description of the legal case, see here: [https://www.leaseholdknowledge.com/oxford-council-leaseholders-have-repair-bills-slashed-from-50000-to-under-4000/]

[121] Emily Brabham who is sustainability lead at Nottingham City Homes gave a compelling account of the complexity of mixed tenure retrofit schemes at a Retrofit Academy webinar in March 2021: [https://www.youtube.com/watch?v=Nh0gnPjtQ-Y]

UK projects. Sanctuary and Platform Housing Group are currently working with the University of Worcester on improving their overall environmental performance of an eco-housing project by adopting a systems approach. Interventions include retrofit options, promoting sustainable behaviour among tenants and the adoption of an Environmental Management System (EMS), among others.[122] The Social Housing Decarbonisation Fund (SHDF) at the Royal Borough of Kensington and Chelsea will fund energy efficiency measures for about 530 homes on the Lancaster West Estate that was home to the Grenfell Tower, totalling £19.4m. Among the partners stand the London School of Economics and the University of Sussex. For several projects in the UK, significant partnerships with universities enabled to provide valuable R&D and capacity for project assessment, data collection about occupants before and after retrofits, and continuous monitoring of properties' thermal and energy performance. For instance, Nottingham City Homes and Nottingham Energy Partnership collaborated with Nottingham University and the University of East London to monitor the effects of the CESP for the Aspley Super Warm Zone scheme (Heba Elsharkawy & Rutherford, 2015; H. Elsharkawy & Rutherford, 2018), and with researchers at Nottingham Trent University to assess and communicate the findings from the REMOURBAN urban district retrofit project in the Sneington neighbourhood (Ianakiev, 2020). Likewise, researchers at Cardiff Metropolitan University collaborated with housing providers to assess the successive retrofit measures of the Welsh government's Arbed scheme (Atkinson, Littlewood, Geens, & Karani, 2015; De Laurentis, Eames, & Hunt, 2017; Littlewood et al., 2017). The landmark Passivhaus retrofit of Wilmcote House in Portsmouth, as part of the European EnerPHit programme, received support from the University of Portsmouth for energy consumption monitoring post-construction, and from the London School of Economics for interviews with residents.[123] Likewise, researchers at the University of Salford and the University of Manchester provided support with post-construction monitoring of thermal performance, participatory project evaluation and knowledge dissemination about the EnerPHit retrofit of Enerley Close at One Manchester (Sherriff et al., 2018). Last but not least, researchers at LSE provided a thorough participatory evaluation of tower block retrofits at Edward Wood estate in Shepherds Bush (at LB Hammersmith and Fulham) that was funded through the CESP and Green Deal Communities. The assessment relied on extensive tenant engagement throughout the two-year retrofit process including an evaluation of occupant satisfaction two years after handover (cf. Bates, Lane, & Power, 2012; Lane, Power, & Provan, 2014). Partnerships with universities have also been conducted for property monitoring for listed properties

European projects. European demonstrator programmes were reviewed as background for this report. These similarly benefitted from the support of academic research groups for the design, coordination and evaluation of various retrofit interventions. In Estonia, a flagship student housing retrofit was initiated by the Technical University of Tallinn which contacted the student housing project about a potential reference property for an EU-funded MORE-CONNECT demonstrator.[124] Another example is the E2B2 partnership ('Research and innovation for energy-efficient construction and living') features complex partnerships between the multi-university RISE research institutes, organisations across the AECOM industry, local councils, and housing providers. Together, they collaborate to provide new knowledge, technology, products and services with a view to deliver the SIRen decision-making methodology. The methodology comprises three components: *a social value assessment, economic viability assessment,* and *environmental life cycle assessment*, including interdependencies between the three. The developed, holistic methodology displays similarities with methodologies developed in the UK (more above).

[122] See the news entry on the Sanctuary Group website [2 June 2021]: [https://www.sanctuary-group.co.uk/news/2021/06/ecohousing-project-set-improve-housing-providers-environmental-performance]

[123] Details of the Wilmcote House Passivhaus deep, step-by-step retrofit can be found here: [https://www.passivhaustrust.org.uk/news/detail/?nId=810#.W_1bM-j7Q2w]

[124] See the summary and complete video for the partnership between the Tallinn University of Technology and the university's student housing provider: [https://www.more-connect.eu/demonstration-project/pilot-homes-estonia/]

Local authority partners

A key insight from the state of the art is the growing role of local authorities as 'enablers' for housing retrofit schemes. This can include access to government funding as well as to develop district heating, not to mention opportunities related to local planning, development management and building control to achieve sustainable buildings, neighbourhoods and districts. Local climate action plans are on the rise as well that seek to involve all segments of society. Local authorities may also have close relationships with Local Economic Partnerships (LEPs), Green Growth Boards, and other cross-sectoral partnerships whose involvement may be keen to build local value chain integration and market maturity for energy-efficient housing retrofits.

Over the years, local authorities and the ALMOs that support them have been able to tap into government funding such as Green Deal Communities, and Green Homes Grant Local Authorities Delivery (LAD) scheme, and the Social Housing Decarbonisation Fund (SHDF). At the same time, some of this funding may unintentionally favour council housing providers and ALMOs at the expense of independent housing associations.

More broadly, the combined challenges of austerity among local authorities and the need for more cohesive local communities point to renewed opportunities in the form of inclusive, multi-organisation partnerships that comprise local authorities, local businesses, community groups and anchors institutions such as housing associations (NHF, 2019).

Community partners

Public-Private-People (4P) partnerships integrate community actors as individual residents, community groups and social enterprises such as energy co-operatives.

In their capacity as 'anchor organisations', housing associations "should apply asset-based community development approaches. These approaches identify and mobilise a community's strengths and target resources accordingly – with the objective of ensuring that services promoting wellbeing and opportunity are delivered effectively to those who need them most." (NHF 'Great Places' report 2019, p.41). The community development work of housing associations can overlap with and strengthen a range of other placemaking as well as participatory planning initiatives. An increasingly popular approach is the 'Superblock', which favours greater community appropriation of the public realm as part of district renovation. Originating from innovative placemaking initiatives at the city of Barcelona,[125] its popularity as a participatory urban planning method has spread across Europe (e.g. Sjöblom et al., 2021), A Superblock approach, combined with more top-down urban district retrofit programmes that incorporate social housing retrofits (e.g. EU-GUGLE), can help strengthen partnerships with the community as well as various 'enhanced' goals in ESG reporting, particularly across the themes of 'resident support', 'placemaking' and 'climate change'.

Noteworthy community initiatives that work with housing and energy retrofits include the Low Carbon Hub (Oxford), the Carbon Co-op (Manchester), some of which may function as one-stop-shops (e.g. BHESco community energy in Brighton and Hove). Relevant partners also include local climate action groups, and catalyst research projects that connect local climate initiatives nationally such as the Place-Based Climate Action Network.[126] One can also cite community-facing platforms that are the dual product of local authority and community initiatives such as Leeds by Example.[127] Community partners also open the way to community financing and blended funding models for net zero

[125] See the following primer about Superblock initiatives by the Commission for Ecology, Urban Planning and Mobility at the city of Barcelona: [https://ajuntament.barcelona.cat/ecologiaurbana/sites/default/files/en_gb_MESURA%20GOVERN%20SUPERILLES.pdf]

[126] See the work of the ESRC-funded Place-based Climate Action Network (PCAN): [https://www.pcancities.org.uk/]

[127] See the Leeds By Example platform which is the product of joint efforts by the community, social enterprise and local authorities: [https://www.leedsbyexample.co.uk/home]

neighbourhoods.[128] A wider community perspective also helps to support a 'just transition' approach and tap into mission-driven, place-based financial tools such as Community Municipal Investments.[129] Similarly, community banks can be attractive partners: the North West Community Bank is a partnership between Wirral Council, Preston City Council, Liverpool City Council and the Community Savings Bank Association to create a council-led regional community bank and invest solely in the local community, including SMEs.

Finally, in connection with the Town Deals[130] and the Community Renewal Fund[131] and build up toward the UK Shared Prosperity Fund in 2022, there are opportunities for housing associations to build on their long-standing engagement with local communities and neighbourhoods. The National Housing Federation (2019, pp. 41-2) highlights renewed opportunities to actively support and empower asset-based community development, and hence focus on local strengths, in areas otherwise categorised as 'deprived' or 'left behind'. Related approaches include 'community wealth building' spearheaded by the National Organisation for Local Economies (CLES), which comprises five pillars: 1) finance in local places; 2) plural ownership of local economy; 3) fair employment and labour markets; 4) responsible procurement of goods and services; and 5) a socially productive use of land and property.[132] For instance, Community Gateway Association (ALMO for Preston City Council) is one of many housing providers who have demonstrated social value impact through community investment, extensive customer engagement, and quality design.[133]

Innovation agencies as partners and activators

As discussed above, innovation agencies and other 'intermediaries' can initiate, activate, and facilitate partnerships and coordinate the delivery of outcomes-based agreements. Based on the learnings from initial demonstrators (both successful and less successful), the partnerships can then replicate, adapt and/or upscale projects. Intermediaries and innovation agency teams can help align needs and objectives iteratively and thereby maintain successful partnership dynamics over the course of projects and programmes. Partnerships primarily operate locally through project design and delivery, whereupon they can share knowledge and experience nationally as well as internationally, as relevant (see for example the Energiesprong, MORE-CONNECT and enerPHit programmes) (more below).

Industry partners

Typical industry partners include contractors and suppliers across the AECOM industry, including architects, retrofit and technology consultants, suppliers of building materials (e.g. EWI modular panels) and renewable energy equipment/installations. Energy Service Companies (ESCos) are also natural partners, as they can tap into ECO schemes for energy efficiency measures that can benefit social landlords. Retrofit partnerships can initiate sector-wide collaborative arrangements rather than just rely on a traditional contracting or procurement approach. Therefore, it makes sense to consider industry actors as 'partners' rather than simply suppliers or contractors. This presupposes mutual trust

[128] See the presentation by Andy Boyle from Otley Energy at a webinar hosted by Ashden [3 June 2021]: [https://www.youtube.com/watch?v=xyaZXu50ZTM]

[129] See the report by PCAN about community municipal investments: [https://pcancities.org.uk/sites/default/files/2020_06_18_PCAN-CMI.pdf]

[130] See the MHCLG overview for the Towns Fund: [https://www.gov.uk/government/news/thirty-towns-to-share-725-million-to-help-communities-build-back-better]

[131] See the overview of the £220 million UK Community Renewal Fund (2021-22) by MHCLG, including all supporting documents: [https://www.gov.uk/government/publications/uk-community-renewal-fund-prospectus/uk-community-renewal-fund-prospectus-2021-22]

[132] See a wide range of community wealth building case studies on the CLES website: [https://cles.org.uk/community-wealth-building-in-practice/community-wealth-building-places/community-wealth-building-case-studies/]

[133] See for example Gateway's Community Impact Report for 2019-2020: [https://www.communitygateway.co.uk/download.cfm?doc=docm93jijm4n1434.pdf&ver=2049]

and shared interests in delivering net zero performance and healthy homes and neighbourhoods simultaneously.[134] Given the state of the art in retrofit innovation, sector-wide partnerships seem more likely to leverage portfolio, interorganisational innovation at scale than strictly competitive or 'atomised' market models.

Learning by doing & knowledge sharing

> *"The potential benefit from sharing our knowledge and practice is a cleaner, greener, healthier planet which many future generations can enjoy."*
>
> Tony Carhill, executive director of property at Livv Housing Group.[135]

In the pursuit of a greener housing sector, innovative retrofit experiments provide unique opportunities to learn from failure (Collins, 2020). Peter Rickaby, technical author of PAS 2035, likewise argues that the sharing of project failures and shortcomings is key for formulating best practice guidance. Openly learning from failure can thereby stimulate sector-wide learning and prevent unnecessary, costly mistakes in the future. The landmark PAS 2035 is the direct output of the 'Retrofit for the Future' programme of affordable housing retrofits (2010-2014) which generated mixed outcomes in terms of retrofit performance. PAS 2035 is required for all new publicly procured works, and contractors are also encouraged to be TrustMark and PAS 2030 certified as a guarantee against the poor workmanship that blighted many projects in past years.

Noteworthy textbook examples of 'bad' practice include a series of EWI retrofit interventions in the Fishwick area in Preston. The retrofit scheme was funded by the Community Energy Saving Programme (CESP) to alleviate fuel poverty among low-income households in properties built in 1900. Conducted at the very end of the funding period in early 2013, poor installations at 390 homes led in some instances to severe water infiltration, damp and mould, causing a serious health hazard to low-income residents without the financial means to pay for repairs. As of 2018, the situation was yet unresolved for many residents.[136] Remediation began in mid-2017 for about sixty homes, which excluded some of the worst-affected homes, for an estimated cost of £1.5m. The unfortunate experience revealed the dramatic effects of poor workmanship, project coordination, and management of defects liability even with the contractual liability period. Less dramatic examples in other projects relate to poor workmanship leading to thermal gaps after EWI installations in such projects as Retrofit for the Future across the UK, and the Arbed 1 area-based retrofit programme in Wales (Hopper et al., 2012; Rickaby, 2021). The Retrofit for the Future programme, while thoroughly designed and assessed, also revealed that success can be contingent rather than planned. Nearly all demonstrator programmes reviewed in this report featured technical and process-related challenges.

Key learnings can also concern partnership arrangements. A noteworthy Dutch demonstrator project in Rotterdam was initiated by a research consortium but was nearly stalled due to the participating social landlord stepping out mid-way through the project. The cause was an estimated 40-year ROI which was deemed too uncertain to bear after second thought.[137] Another project iteration took stock

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[134] Presentation by David Kemp (ProcurePlus) in RetrofitAcademy Summit 2020: [https://www.retrofitacademy.org/retrofit-for-social-housing-online-summit/]

[135] See the blog entry on Unlock Net Zero [11 June 2021]: [https://www.unlocknetzero.co.uk/news/welcome-net-zero-as-an-opportunity-to-create-path-for-others-to-follow]

[136] See the online media coverage of the poor retrofit works here: [https://passivehouseplus.ie/news/health/disastrous-preston-retrofit-scheme-remains-unresolved]

[137] The 2ndSKIN partnership is a demonstrator between several EU universities, EIT Climate-KIC, a housing organisation providing both social and cooperative housing, and building start-up. The final report for the first iteration of the 2nd SKIN project can be found here: [https://projecten.topsectorenergie.nl/storage/app/uploads/public/591/0af/4f7/5910af4f7e25b894647774.pdf]

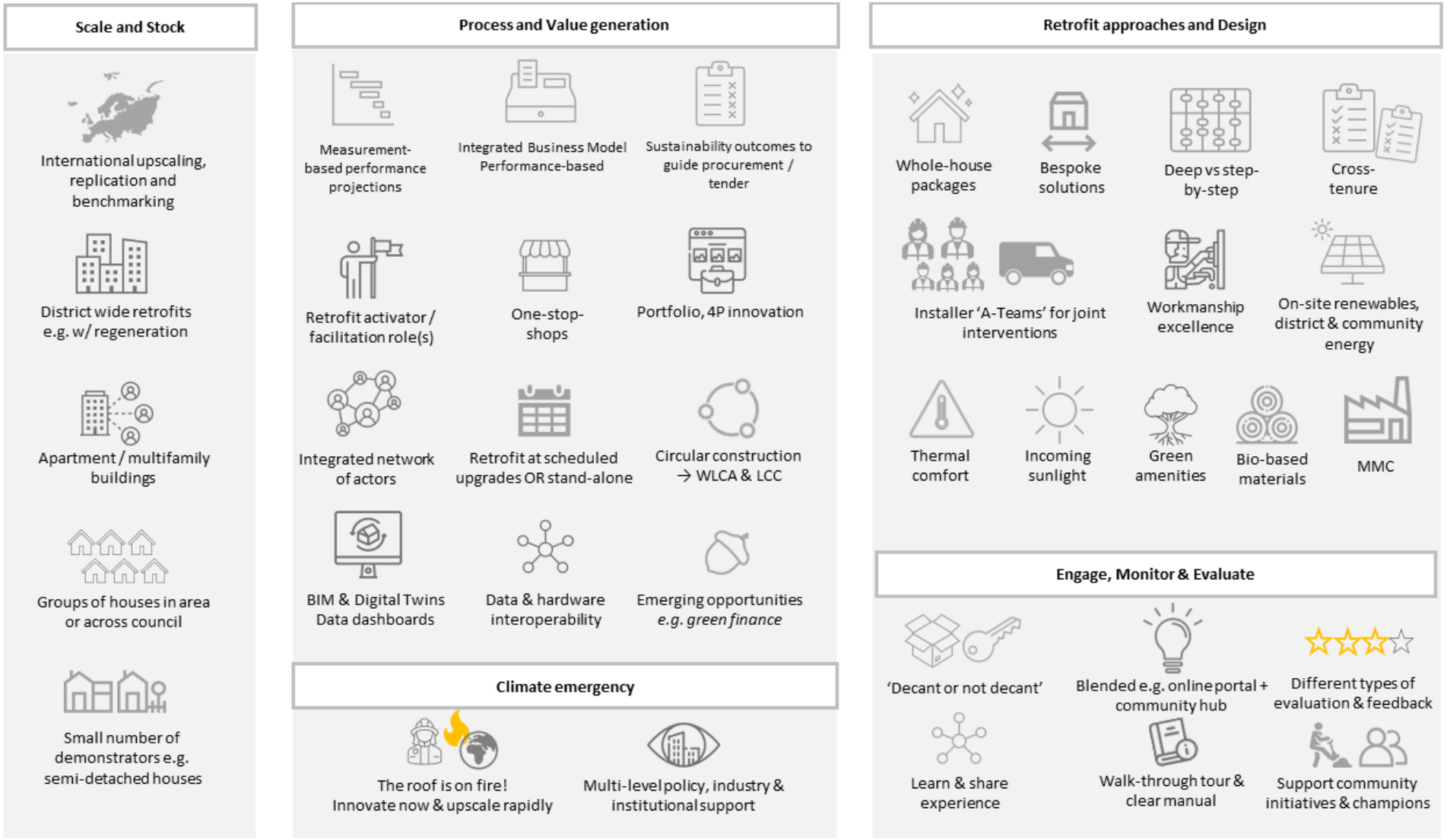
of previous learnings and successfully delivered a deep retrofit of 12 apartments at a new location (in Vlaardingen), where the lightweight façade developed through the project could at last be implemented. Complications in such externally-funded partnerships arise from a project focus. The potential 'projectification' of retrofit innovation can potentially limit partnerships' capacity to deliver impactful and scalable retrofit interventions in the long-term. Instead, they may be useful in supporting partnerships as 'market-enablers' or 'market-creators' and in supporting the development of subsidy-free business models, at least by design, if not in reality.[138]

Conceptual framework

The proposed conceptual framework provides a synthetic overview of the social-technical issues that affect energy-efficient social housing retrofits and innovation. The framework therefore enables to pull everything together and helps to bridge theory and practice.

[138] See for example the Energiesprong model, which is beginning to deliver on some of its objectives. The average retrofit investment cost of £75,000 per property is however well above the £20,000-£25,000 mark emerging from an Inside Housing survey and the 'Retrofit for the Future' programme, respectively.

Figure 11 - Conceptual framework for multi-organisational portfolio retrofit innovation, based on the state of the art

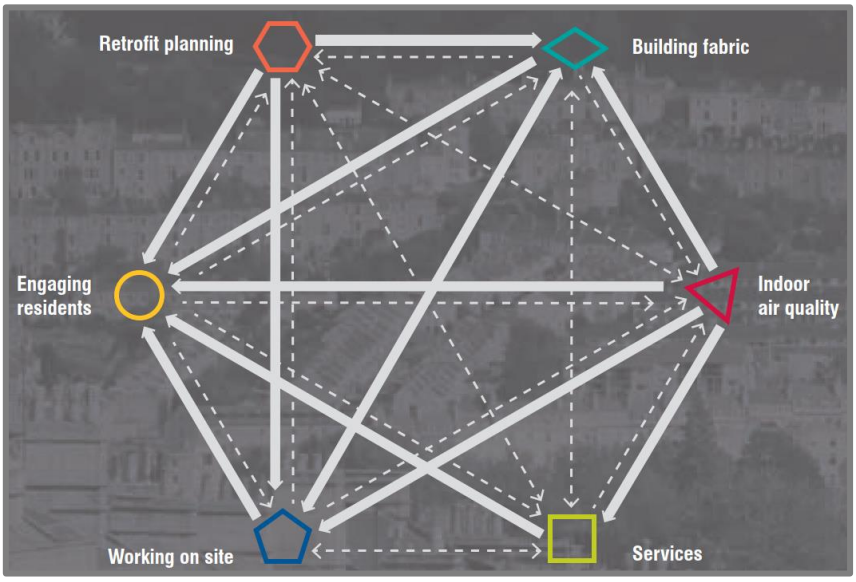


Methodological innovation for greener futures

The climate challenge calls for a 'revolution' in energy-efficient retrofits. Likewise, philosopher of science Thomas Kuhns famous investigated the dynamic of scientific revolutions, albeit as an almost invisible process (Kuhn, 2012 [1962]). Citing Kuhn, Flyvbjerg (2006, p. 242) highlights the importance of aggregate insight from a large range of case studies to formulate best practice: "a discipline without a large number of thoroughly executed case studies is a discipline without systematic production of exemplars, and that a discipline without exemplars is an ineffective one. In social science, a greater number of good case studies could help remedy this situation." A similar case was already made in defence of well-conducted 'case surveys' that enable to leverage granular insight at scale (W. A. Lucas, 1974). Critically, an aggregate or 'porfolio' case study approach enables reflection in action, or reflective practice (Flyvbjerg, 2006; Schon, 1984). Such is the key insight drawn from the Retrofit for the Future programme shared by Peter Rickaby, which directly helped to shape the publication of the PAS 2035 framework. Key insight from the programme is summarised in the guidance report by TSB (2014), which focuses on 40 out of the 115 retrofitted home. Likewise, longitudinal, comparative insight from the GFP demonstrators promises to drive both practical and theoretical insight seamlessly.

Retrofit innovation is inherently a complex 'socio-technical' process that interlinks people, properties, places, and policy with emerging technologies. All components need to be considered and integrated carefully to produce a range of different, fit-for-purpose and future-proof energy-efficiency interventions. The report by TSB (2014) maps six key components: *retrofit planning, building fabric, indoor air quality, services, working on site, and engaging residents*. Figure 10 displays the direction and strength in the observed thematic interdependencies.

Figure 12 - Degree of connection between the six themes - key insight from 40 homes from the Retrofit for the Future programme (TSB, 2014)



The TSB (2014) insight provides a framework of sorts, that considers both technical, project management, human and indoor-environmental dimensions. Perhaps unsurprisingly, this categorisation overlaps with the outputs from other retrofit innovation programmes. For instance, the research-led SIRen ('Sustainable Integrated Renovation') Partnership in Sweden produced a practical guidance document that proposes a fivefold categorisation (human, environmental, technical, economic and process-related issues), comprising twelve sub-categories. The methodology can be operationalised by specific project stakeholders/actors as a spider diagram for baseline evaluation, design, monitoring and post-occupancy evaluation (Table Z).

Although engaging residents was recognised as a key component, the report indicates it had only a moderate influence on the other components (TSB, 2014). Adopting a user-centred approach to

retrofits as socio-technical systems that merge human and technological components seamlessly (Balest & Vettorato, 2018; Kaptelinin & Nardi, 2012), one could make the case for methodological innovation that places tenant engagement at the heart of the matter. Currently, the state of the art indicates the emerge of elaborate innovation partnerships that aim to leverage affordable, bespoke retrofit solutions at scale. These can qualify as Public-Private Partnerships (PPPs) and/or inter-organisational partnerships of various kinds. These are often part-funded and/or supported by expert innovation agencies, working in collaboration with local councils for funding or district and community energy supply. The next frontier for methodological innovation perhaps lies in 4P models, namely: Public-Private-People Partnerships. The stakes are both practical and epistemological: residents as customers/tenants/community leaders/home stewards fulfil multiple roles and aspirations, habits, awareness and capacity for personal and collective transformation that can either empower or stall energy-efficiency measures. More than assets or liabilities, people are key stakeholders in partnership enterprises.

Finally, a recursive approach 4P partnerships considers people as present in each of the four 'P's: public organisations, companies and partnership coordinators themselves operate as people rather than abstract organisational entities or institutions. Likewise, objects can be seen as stakeholders in their own right. For example, Whole Life Cycle and Life Cycle Costing assessments explicitly take into account the direct influence of a web of environmental and produced materials and technological artefacts on the overall carbon and indoor environmental performance of buildings. An innovative socio-technical methodology can therefore engage with materials things and objects as partners or 'actors' in their own right. Among others, these include building materials, renewable energy equipment, community energy and district heating networks, green amenities and digital technologies such as sensor data, BIM, and smart meters. In the common parlance of Science and Technology Studies (STS), actors comprise both objects (e.g. 'technology') and living organisms (e.g. 'people').[139] To put both the living and the lifeless on the same level plane in terms of their role, they are called 'actants'. The mapping of the complex, lived relationships between different actors takes shape as 'actor-networks'. Actor-networks are a way of observing, understanding and actively engaging in the relationships between actants. More than a conceptual activity, actor-networks help to make sense of the many ways in which people and technology shape each other recursively. Indeed, the state of the art provides ample evidence that retrofit innovation hinges on methodological innovation at all scales, from the granular level of expertly-conducted on-site installations to the strategic level of retrofit coordination. In sum, an elaborate socio-technical approach can both operationalise and make sense of a 4P, portfolio model to the collaborative design, delivery, and evaluation of energy-efficient retrofits, as underpinned by continuous, on-site monitoring.

Knowledge gaps and opportunities

The state of the art identifies multiple, interrelated knowledge gaps and opportunities for multi-organisational innovation portfolios. These can be investigated together or as stand-alone projects, as appropriate.

Performance gaps

The state of the art and conceptual framework highlight several, interdependent gaps in knowledge and implementation. Primarily, these concern performance, thermal and skills gaps. Current procurement practices based on estimated energy savings calculations (i.e. SAP and rdSAP based on EPC-rating averages for property types) typically leads to an overestimation of actual energy savings, which affects both ROI, and collective trust in retrofits approaches as well as, potentially, the reputation of industry stakeholders. The effects in performance gaps are especially severe for deep, whole-house retrofits as these incur a larger up-front investment and longer-term ROI.

[139] See the following overview of Actor Network Theory (ANT), and the work of scholars such as Bruno Latour, Michel Callon and John Law: [https://www.sciencedirect.com/topics/earth-and-planetary-sciences/actor-network-theory]

Mapping customer goals to net zero carbon outcomes

This report features a grid of goals for retrofits from an organisational perspective. A similar grid could be developed with a user-centred focus, for example through extensive customer involvement and co-production. This would help reverse the top-down, traditional view on achieving net zero carbon in the housing sector. Inconsistencies in government retrofit policy objectives have notably been revealed in the TPAS and PlaceShapers consultation of social housing tenants (2021). A bottom-up, user-led approach could help shed light on both real needs and experiences of end-users, including their own possible active contribution to building and nurturing sustainable communities. A precedent includes the climate jury of tenants set up by the Northern Housing Consortium.[140] Customer engagement around net zero targets, and potentially the regenerative economy, will likely need to address more structural issues that underpin fuel poverty, and the other areas of concern revealed by the 2019-2020 English Survey that shape customers' wellbeing and perceived opportunities.

Overcoming stigma in and beyond energy efficiency measures

Overlapping with the above, comprehensive retrofit and regeneration measures need to tackle social stigma as well as buildings' thermal performance. Indeed, area-based programmes aiming to deliver energy efficiency may fall short of addressing the structural issues that underpin low income and fuel poverty (Reid, McKee, & Crawford, 2015). Ejogu and Denedo (2021) provide a thorough analysis of the enduring stigma attached to social housing in England that may indirectly challenge the effectiveness or add complexity to innovative retrofit programmes. The report underscores the need to put customers' voice at the heart of service design and delivery, notably through deliberation and co-production, alongside wider collective efforts across society. The cross-cutting recommendations emerging from the 'See the Person' campaign also need to be further amplified and streamlined on the road to net zero carbon in social housing (see Davis, 2020).

Demonstrator database

While this report reviews flagship projects in social housing, it is impossible to provide a fully comprehensive and up-to-date review of all noteworthy retrofit projects in the UK, let alone in Europe. A valuable research and industry output for both the GFP and the wider housing sector (including government), would be to compile a rich database of retrofit projects. Importantly, the review of retrofit projects showed that project evaluation is inconsistent and unsystematic, thereby greatly limiting benchmarking across the sector as a whole. Critically, the database should feature both flagship projects and projects deemed unsuccessful. Indeed, *actively learning from failure* will help housing providers and other property stakeholders save millions of pounds and help steer investment strategies, retrofit design, project coordination, workmanship and job creation in the right direction. The database could be populated with projects from 2010 onward, and favour whole-house approaches (whether deep or step-by-step), and be as transparent and complete as possible. Data collection about projects would be systematic and consistent, and the methodology would be piloted initially with voluntary organisations. Project variables could include retrofit cost per property, type and amount of funding, tenure, occupant profile, property archetype, and so on.

A useful point of departure is the online Low Energy Building Database that was created as part of the Retrofit for the Future (RfF) programme (2010-2014). An up-to-date database could therefore build on the experience of this platform as well as the systematic monitoring approach adopted for the RfF programme, although cost analysis was only commissioned post-hoc, leading to important cost data not having been captured for a number of projects. Such publicly available, comprehensive and up-to-date database would benefit the sector as a whole, for example focusing on social housing retrofits and/or new build exemplars that demonstrate the effectiveness of different affordable energy efficiency measures and partnership arrangements. The value proposition of the database would be

[140] See the account by the Chief Executive of the Northern Housing Consortium on Inside Housing (9 June 2021): [https://www.insidehousing.co.uk/comment/putting-tenants-voices-at-the-heart-of-the-transition-to-net-zero-71013?utm_source=Ocean%20Media%20Group&utm_medium=email&utm_campaign=12449058_IH-ASSET-MANAGEMENT-11-6-2021-GR&dm_i=1HH2,7ETR6,6F7RZG,U3NWL,1]

to provide an evidence-based decision support tool for housing, policy and research professionals. In turn, it could help create and be fed by communities of practice in benchmarking the state of the art in affordable retrofit innovation.

Sustainability gap

Another knowledge gap concerns the unresolved, inherent tensions between economic, social and environmental value that lie at the heart of sustainable development. Particularly, there may be a paradox in seeking to pursue a least-cost approach, while also aiming to score highly on the 48 Environmental, Social and Governance (ESG) reporting criteria. Recent frameworks favour a systemic approach to value generation (considering project viability, community benefits and environmental quality simultaneously). However, one can hypothesise that these may be difficult to deliver or measure consistently in practice.[141] A pending research question therefore is: "to what extent can green procurement and green financing transcend narrow growth models that externalise social and environment costs, and instead deliver systemic value and innovation?"

Preventing homelessness by future-proofing homes

The complex conditions that lead to and feed homelessness are beyond the scope of this paper. However, delivering energy-efficient retrofits can significantly improve people's wellbeing and life chances, as recognised in policy and across the housing sector. Holistic approach to value propositions can integrate wider community benefits. These can be evidenced through enhanced ESG reporting, continuous customer involvement, and demonstrator programmes. Multi-organisational retrofit portfolio innovation can therefore help operationalise recommendations formulated in such reports as 'Targeting energy efficiency renovation to improve housing conditions of the most vulnerable' by the European Federation of National Organisations Working with the Homeless (FEANTSA, 2021).[142] As mass roll-outs in retrofits are likely to overlap with wider neighbourhood regeneration efforts and development in the future, they can also implement some of the recommendations in Shelter's 'Building for our Future: A vision for social housing' report.[143]

Partnerships

Zero-carbon social housing is one of the many 'wicked' problems within the broader aim of achieving sustainability the built environment and attractive neighbourhoods and cities.

Joint investments in property retrofits and urban regeneration could further explored to minimise risks and generate greater collective benefits. Depending on the context and location, there might be opportunities for such joint endeavours to connect the needs of tenants and local communities simultaneously as part of agile or flexible local development plans and comprehensive plans in the future. Further research could investigate the extent to which a wide range of stakeholders could help leverage district-wide investments. A key input would be that of Local Energy Hubs and the Local Entreprise Partnerships (LEPs) that support them, and various innovative PPP partnerships involving the AECOM and planning industries. Importantly, future innovation must consider whole-life cycle approaches to assess the carbon and wider environmental performance of projects. Toward this end, various complementary and interlocking tools, standards and frameworks are readily available, ranging from the RIBA Sustainable Outcomes Guide and the Social Value Toolkit to PAS 2035.

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[141] See the account by Sarah Smith about difficulties surrounding the first annual round of ESG reporting at Optivo (14 July 2021): [https://www.housing.org.uk/news-and-blogs/blogs/sarah-smith/environmental-social-and-governance-reporting--our-experiences/]

[142] The FEANTSA report can be found here along with a short summary (2021): [https://www.buildup.eu/en/practices/publications/targeting-energy-efficiency-renovation-improve-housing-conditions-most]

[143] The final report of Shelter's Commission on the future of social housing: https://england.shelter.org.uk/support_us/campaigns/a_vision_for_social_housing

Long-term investment also requires long-term commitment. Continuous monitoring of as-built performance seems key to measure real savings and co-generated benefits, as does the need to go beyond a project-focus and move toward a 'multi life cycle' focus. The 'projectification' of both planning and property sector is effective at delivering short-term effects, sometimes with great shared value. However, a project-logic is not always effective in internalising environmental costs (and related benefits) in the long run. As discussed above, there are perhaps greater benefits to be considered in consider multiple life cycle effects across projects, in conjunction with wider placemaking efforts at the neighbourhood, district, city, metropolitan and regional scales. Depending on project needs and evolving policy and industry opportunities, multiple sources of cross-sectoral funding, value co-generation streams, and de-risking could be sourced at different spatial, administrative, and organisational scales. Unfortunately, there is ready-made, off the shelf approach that combines low-cost net-zero retrofit with neighbourhood regeneration, as both properties and neighbourhoods require bespoke solutions.

Innovation funding

'Outside the box' opportunities include greater expectations on research impact from funding research councils on the one hand, and the large number of EU-funded and international innovation consortiums on the other. Complex funding and investment streams would thereby likely include any or all of the following: 1) various form of government *grants and subsidies* (as current); 2) u*niversity-led research innovation funding* (e.g. via Innovate UK, Connected Cities Catapult, H2020 bids); 3) *EU innovation funding* (e.g. Climate KIC programmes, H2020 bids); 4) potential funding from *corporate foundations* for circular construction, renewable energy and energy efficiency; and 5) *community-based forms of funding*, such Community Municipal Investment, co-operative energy, and crowdfunding. Actors such as Vivid Economics and Bankers without Boundaries investigate innovative forms of blended funding to fuel the climate transition in the built environment.[144] Additionally, comparative empirical research could investigate the potential for new housing ownership models that combine cooperative, social and/or community housing, as well as mixed tenure evolutions over time (e.g. 'right to rent' evolving into 'right to buy'). For instance, some housing providers offer both cooperative and social housing. These may open the way to different forms of value generation and shared investment. Considering an evolutive approach to mixed tenure, current policy recommendations suggest increased property values may be associated with sliding stamp duties that favour higher energy efficiency performance. Socially rented properties may be sold over time. Perhaps there is also room for Compulsory Purchase Orders to acquire and renovate empty properties for social rent and convert economically less attractive office space (due to increased remote working) into healthy and efficient social housing.

[144] See for example the recent report by Vivid Economics entitled 'Financing innovation and transformation in the UK residential built environment sector' [March 2021]: [https://cp.catapult.org.uk/wp-content/uploads/2021/03/CPC-Vivid-Economics-2021-Financing-Innovation-in-the-UK-Residential-Built-Environment-Sector.pdf]

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Appendices

Appendix I - Local Agenda 21 programmes: a vignette

Current social housing retrofit programmes can benefit from the learnings and comprehensive approach to sustainable development of former Local Agenda 21 programmes. Local Agenda 21 (LA21) programmes represented a landmark effort to bolster community initiatives toward sustainable development across the world, adopting the famous motto 'Think global, act local'. Ushered by the United Nations Earth Summit in Rio in 1992, LA21 was reaffirmed as an important tool for sustainable development at the UN World Summit on Sustainable Development in Johannesburg in 2002. The Joseph Rowntree Foundation commissioned a report about community- and council-led LA21 programmes conducted as part of neighbourhood regeneration programmes in 8 local councils across the UK. The LA21 programmes featured such varied initiatives as energy-saving measures, recycling and community gardening, among others (K. Lucas, Ross, & Fuller, 2003). Key findings highlighted that LA21 programmes were generally perceived as foreign by local residents, as they were not typically engaged from the start, although the need for an integrated approach to sustainable development was widely recognised and supported. LA21 strategies were also not always effective in rolling-out joint actions toward economic, social and environmental sustainability simultaneously. Furthermore, the programmes suffered from a lack of coordination among the different actors working toward greater sustainability in the deprived neighbourhoods, resulting in some duplication of actions and lack of awareness of concurrent local initiatives.

The report recommended a greater consideration of the following: 1) a community-centred, needs-based approach; 2) a combined bottom-up and top-down approach; 3) intra-organisational collaboration across departments; 4) easily accessible funding streams that meet local community needs; 5) an adequate supply of additional resources in terms of time skills, time and energy to support front-line workers, volunteers and community representatives and prevent unnecessary burn-outs; 6) designing and sharing appropriate methodologies among all parties involved; 7) a bespoke, comprehensive evaluation mechanism that considers both traditional quantitative measures and qualitative measures that are meaningful to local residents and other stakeholders (JRF, 2003).

Almost twenty years on, these lessons from LA21 programmes remain topical for current efforts toward sustainable neighbourhoods, which net-zero carbon social housing retrofits can simultaneously contribute to and benefit from. The methodological importance of a community-centred approach and bespoke evaluation measures remains highly topical for achieving truly sustainable net-zero carbon in social housing. Aggregate experience from LA21 programmes have also informed the UN Agenda 2030 and its operationalisation through the Sustainable Development Goals. In turn, recent policy documents and frameworks for energy efficiency in housing explicitly address these cross-cutting SDGs.

Selective list of repositories of case studies

Passivhaus social housing exemplars in the UK (both new build and retrofits/regeneration): [https://www.passivhaustrust.org.uk/competitions_and_campaigns/passivhaus-for-local-authorities/#Social%20Housing%20case%20studies]

Database and map of Passivhaus projects in the UK: [https://passivhausbuildings.org.uk/passivhaus.php]

Low energy buildings project UK database by the AECB for projects delivered since 2010, initially for the Retrofit for the Future programme (2010-2014). As of July 2021, it features 197 social housing properties, both new build and retrofits, including several that are listed or in conservation areas: [https://www.lowenergybuildings.org.uk/projectbrowser.php]

EU-GUGLE programme case studies for smart district regeneration and social housing retrofit case studies: [http://eu-gugle.eu/pilot-cities/]

Essential reading & resources

Context and policy

Barriers to retrofit in social housing (Palmer et al., 2018) commissioned by BEIS - interviews with 40 social landlords and 8 retrofit suppliers: [https://www.gov.uk/government/publications/barriers-to-retrofit-in-social-housing]

The Decent Homes Standard (DCLG, 2006): [https://www.gov.uk/government/publications/a-decent-home-definition-and-guidance]

Each Home Counts (Bonfield, 2016) commissioned by BEIS and DCLG: [https://www.gov.uk/government/publications/each-home-counts-review-of-consumer-advice-protection-standards-and-enforcement-for-energy-efficiency-and-renewable-energy]

Fuel Poverty Strategy - '**Sustainable Warmth'** report (BEIS, 2021): [https://www.gov.uk/government/publications/sustainable-warmth-protecting-vulnerable-households-in-england]

The Full Cost of Poor Housing [no less than £1.4bn for the NHS and £18.6bn for wider society!] by Roys et al. (2016) for BRE: [https://www.bregroup.com/buzz/the-full-cost-of-poor-housing/]

The Full Cost of Poor Housing in Wales by Nicol et al. (2019) for BRE Trust, Public Health Wales and the Welsh Government: [https://phw.nhs.wales/news/the-cost-of-poor-housing-in-wales/the-full-cost-of-poor-housing-in-wales/]

Greener Homes (RIBA, 2019): [https://www.architecture.com/-/media/GatherContent/Paywalled-resource-with-many-PDFs-VPC/Additional-Documents/GreenerHomespdf.pdf]

Greening our existing homes: National Retrofit Strategy – consultative document by the Construction Leadership Council (2021): [https://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2020/12/CLC-National-Retrofit-Strategy-final-for-consultation.pdf]

Greener Recovery policy paper by the Landscape Institute (2020): [https://landscapewpstorage01.blob.core.windows.net/www-landscapeinstitute-org/2020/09/12332-greener-recovery-v6.pdf]

UK housing: Fit for the Future? By the Climate Change Committee (2019): [https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/]

The New Homes Policy Playbook: Driving sustainability in new homes – a resource for local authorities (UKGBC, 2021): [https://www.ukgbc.org/wp-content/uploads/2021/01/New-Homes-Policy-Playbook-January-2021.pdf]

Tackling fuel poverty, reducing carbon emissions and keeping household bills down: tensions and synergies – Report to the Committee on Fuel Poverty by Bridgeman et al. (2018), Centre for Sustainable Energy: [https://www.cse.org.uk/downloads/reports-and-publications/fuel-poverty/policy/insulation-and-heating/policy-tensions-and-synergies-CFP-mainreport-may-2018.pdf]

'Targeting energy efficiency renovation to improve housing conditions of the most vulnerable' by the European Federation of National Organisations Working With the Homeless (FEANTSA, 2021): [https://www.feantsa.org/en/report/2021/03/19/targeting-energy-efficiency-renovation-to-improve-housing-conditions-of-the-most-vulnerable?bcParent=27]

The Ten Point Plan for a Green Industrial Revolution: Building back better, supporting green jobs, and accelerating our path to net zero, policy paper (BEIS, 2020): [https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution]

'An Alternative Ten Point Plan to achieve net zero emissions in the UK by 2030' by BHESCo (2020): [https://bhesco.co.uk/blog/ten-point-plan-net-zero-emissions-uk-2030]

Standards toolkits and frameworks

BREEAM Sustainable refurbishment of domestic buildings (2014) – 1) *briefing paper***:** [https://tools.breeam.com/filelibrary/Brochures/63945---Sustainable-refurbishment-of-domestic-buildings-using-BREEAM.pdf] - and 2) *technical document*:[https://www.breeam.com/discover/technical-standards/refurbishment-and-fit-out/]

Living Building Challenge by the International Living Future Institute (2019): [https://living-future.org/lbc/]

Living Community Challenge by the International Living Future Institute (2017): [https://living-future.org/lcc/]

Regenerative Construction and Operation - RESTORE EU Cost Action research programme about integrating a regenerative economic approach throughout the lifecycle of projects from procurement and design to future life (2019): [https://www.eurestore.eu/wp-content/uploads/2019/07/RESTORE-WG3-Booklet.pdf]

One Planet Living Framework by Bioregional (2019): [https://www.bioregional.com/resources/one-planet-living-for-sustainable-places]

PAS 2035, explained by the Retrofit Academy: [https://www.retrofitacademy.org/what-is-pas-2035/]

Passivhaus construction costs (Passivhaus Trust, 2019): [https://www.passivhaustrust.org.uk/UserFiles/File/research%20papers/Costs/2019.10_Passivhaus%20Construction%20Costs.pdf]

Passivhaus social housing: Maximising benefits, minimising costs (Passivhaus Trust, 2019): [https://www.passivhaustrust.org.uk/guidance_detail.php?gId=42#.XN6m8jG2k2w]

Passivhaus: the route to net zero carbon? (Passivhaus Trust, 2019): [https://www.passivhaustrust.org.uk/UserFiles/File/2019.03.20-Passivhaus%20and%20Zero%20Carbon-Publication%20Version1.2(1).pdf]

RIBA 2030 Climate Challenge version 2 (2021): [https://www.architecture.com/-/media/files/Climate-action/RIBA-2030-Climate-Challenge.pdf]

RIBA Plan of Work (2020) - *Overview*: [https://www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/2020RIBAPlanofWorkoverviewpdf.pdf] | *A4 Template*: [https://www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/2020RIBAPlanofWorktemplatepdf.pdf]

RIBA Sustainable Outcomes Guide (RIBA, 2019): [https://www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/RIBASustainableOutcomesGuide2019pdf.pdf]

TrustMark PAS 2035 & PAS 2030: [https://www.trustmark.org.uk/ourservices/pas-2035]

WELL Community Standard: [https://v2.wellcertified.com/community/en/overview]

Definitions, targets and metrics

Net Zero Carbon Buildings: A framework definition (UKGBC, 2019): [https://www.ukgbc.org/ukgbc-work/net-zero-carbon-buildings-a-framework-definition/]

Rethink Retrofit – survey of over 100 built environment professionals by Longitude for WSP (2020): [https://visual-stories.wsp.com/retrofit3]

The Retrofit Playbook by the UK Green Building Council (UKGBC, 2020): [https://www.ukgbc.org/ukgbc-work/driving-retrofit-of-existing-homes/]

Whole life carbon assessment for the built environment by RICS (2017): [https://www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf]

Retrofit components

UK BIM Framework – extensive guidance about related standards for Building Information Modelling (mainly ISO 19650 series): [https://www.ukbimframework.org/standards-guidance/]

The Draft Design Guide by Cornwall County Council (2020): [https://www.cornwall.gov.uk/designguide] including PDF version: [https://www.cornwall.gov.uk/media/ngxlkwb2/cornwall-design-guide-consultation-draft-no-pop-ups.pdf]

London Housing Design Guide (Design for London, 2021): [https://www.london.gov.uk/sites/default/files/Interim%20London%20Housing%20Design%20Guide.pdf]

Modern Methods of Construction: A forward-thinking solution to the housing crisis? (RICS, 2018): [https://www.rics.org/globalassets/rics-website/media/news/news--opinion/modern-methods-of-construction-paper-rics.pdf]

Modern Methods of Construction report by the Housing, Communities and Local Government Committee (House of Commons, 2019): [https://publications.parliament.uk/pa/cm201719/cmselect/cmcomloc/1831/1831.pdf]

Modern Methods of Construction - Resources

- Key insight by leading MMC consultancy Akerlof: https://akerlof.co.uk/insight
- Methodology for quantifying the benefits of offsite construction: https://www.ciria.org/ItemDetail?iProductCode=C792F&Category=FREEPUBS&WebsiteKey=3f18c87a-d62b-4eca-8ef4-9b09309c1c91

National Model Design Code (MHCLG, 2021): [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957205/National_Model_Design_Code.pdf]

Passepedia: a one-stop repository of Passive House resources, covering all aspects of EnerPHit retrofits and Passivhaus new builds: [https://passipedia.org/]

The Sustainable Renovation Guide by Chris Morgan (John Gilbert Architects) for the Pebble Trust with SEDA, and Historic Environment Scotland: [https://static1.squarespace.com/static/5978a800bf629a80c569eef0/t/5beca5f021c67c2280e66de3/1542235691571/Guide+to+Domestic+Retrofit.pdf]

Retrofit approaches

Energiesprong UK – 1) *technical documentation*: [https://assets.website-files.com/59944999990f53000134107e/5c1ba33102ca997b97716063_0.%20NEF%20ES%20TECH%20Guidance%20-%20Index.pdf] and 2) *general leaflet*: [https://assets.website-files.com/59944999990f53000134107e/5bc876863f1abb6b3085fde3_ES-leaflet-long_version.pdf]

EU-GUGLE approach combining large-scale social and low-income housing retrofits with smart city development (builds on the SINFONIA EU project): [http://eu-gugle.eu/wp-content/uploads/2013/10/eugugle-leaflet-en-def.pdf]

Green Deal, Energy Company Obligation and Traditional Buildings. Technical paper by Hay and colleagues (2013) at Changeworks for Historic Scotland, which investigates partial and whole-house retrofits of historic buildings, include the u-values and costs of specific interventions for three main archetypes (sandstone cottage, tenement flat, and granite cottage): [https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=d3cc13e0-f84a-4c39-bfb4-a59400a9952d]

REMOURBAN Urban Regeneration Model (2020): [http://www.remourban.eu/technical-insights/best-practices-e-book/best-practices-e-book.kl]

Retrofit for the Future (2010-2014)- see analysis of the projects here, including cost analysis, project data and best practice recommendations: [https://www.ukgbc.org/ukgbc-work/retrofit-for-the-future-innovate-uk/].

Retrofit Social Housing: Better Homes Improve Lives – summary report of REMOURBAN retrofits at Nottingham City Homes in the Sneinton neighbourhood (2020): [http://www.remourban.eu/technical-insights/insights/retrofit-social-housing-better-homes-improve-lives.kl]

Scaling Up Retrofit 2050 report by IET and Nottingham Trent University: [https://www.theiet.org/impact-society/factfiles/built-environment-factfiles/retrofit-2050/]

SINFONIA EU project. Assessing the multiple benefits of combining housing retrofits with smart city development (2020): [https://www.mdpi.com/2071-1050/12/19/8038]

Step-by-step retrofits with Passive House components by the Passive House Institute (2016): [https://europhit.eu/sites/europhit.eu/files/EuroPHit_Handbook_final_Optimized.pdf]

Customer and community engagement

The Charter for Social Housing Residents White Paper (MHCLG, 2020): [https://www.gov.uk/government/publications/the-charter-for-social-housing-residents-social-housing-white-paper/the-charter-for-social-housing-residents-social-housing-white-paper]

Engaging for the Future, report by Commonplace (2021) based on the cumulative experience of hundreds of public consultation projects: [https://www.commonplace.is/ebook-engaging-for-the-future]

Great Places Commission's Final Report: Ten recommendations for creating great places to live (National Housing Federation, 2019): [https://greatplaces.housing.org.uk/about-great-places/great-places-final-report]

High Rise Hope: the social implications of energy efficiency retrofit in large multi-storey tower blocks, focusing on the Passivhaus retrofit of Wilmcote House at Portsmouth City Council (Bates et al., 2012): [http://eprints.lse.ac.uk/47123/] *followed by* → **High Rise Hope Revisited**: the social implications of upgrading large estates (Lane et al., 2014): [http://eprints.lse.ac.uk/67854/]

Maximising the benefits of Passivhaus: A guide to supporting older tenants by the Institute for Collaboration on Ageing (University of Manchester), One Manchester and Housing LIN (2015): [https://www.housinglin.org.uk/Topics/type/Maximising-the-Benefits-of-Passivhaus-A-Guide-to-Supporting-Older-Occupants/]

Participedia is a world-class, crowdsourced repository for participatory methods and tools in placemaking, community development and resident engagement, launched by leading scholars in the field: [https://participedia.net]

Residents' voices in the UK's Net Zero Carbon Journey by Placeshapers and TPAS (Bryson, 2021): [https://www.placeshapers.org/residents-voices-in-net-zero-carbon-journey/]

Together with Tenants: Lessons from the early adopter programme (NHF, 2020): https://www.housing.org.uk/globalassets/files/together-with-tenants/together-with-tenants---early-adopter-report_final.pdf

TPAS National Tenant Engagement Standards (2021): [https://www.tpas.org.uk/standards]

TPAS Leaseholder Engagement Guide (2015): [https://www.tpas.org.uk/ebooks/download-form/4]

Business models, value and co-benefits

ESG Reporting Standard for Social Housing Final report of the ESG Social Housing Working Group (2020): [https://esgsocialhousing.co.uk/wp-content/uploads/2020/11/SRS_final-report-2.pdf]

Financing energy efficient buildings: the path to retrofit at scale by the Green Finance Institute (2020): [https://www.greenfinanceinstitute.co.uk/report-financing-energy-efficient-buildings-the-path-to-retrofit-at-scale/]

Financing innovation and transformation in the UK residential built environment sector by Connected Places Catapult and Vivid Economics (2021): [https://cp.catapult.org.uk/wp-content/uploads/2021/03/CPC-Vivid-Economics-2021-Financing-Innovation-in-the-UK-Residential-Built-Environment-Sector.pdf]

Financing best practice for EnerPHit refrofits (to Passivhaus standard) - insight and resources from the EuroPHit programme (~2016): [https://europhit.eu/finance]

Social Value Guidance, Standards and Tools for SROI by Social Value UK (including templates): [https://socialvalueuk.org/resources/sroi-guide/]

Social Value and Design of the Built Environment – aligned with RIBA 2013 Plan of Work (Social Value UK, 2017): [https://socialvalueuk.org/wp-content/uploads/2017/12/social-value-and-design-of-the-built-environment-v-02-oct-2017.pdf]

Social Value Toolkit for Architecture (RIBA and University of Reading, 2020): [https://www.architecture.com/-/media/GatherContent/Social-Value-Toolkit-for-Architecture/Additional-Documents/RIBAUoR-Social-Value-Toolkit-2020pdf.pdf]

The Value Toolkit by the Construction Innovation Hub (2021): [https://constructioninnovationhub.org.uk/value/]

Partnerships & portfolio innovation

The best point of departure is the consortiums created as part of international retrofit programmes (see essential reading under ‘Retrofit approaches’).