

Define the Need

Why we need to transform the retrofit market and how



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Introduction to Transform-ER



Retrofitting the UK housing stock is critical to meet net zero targets and improve the comfort and health of occupants.

However, multiple challenges and barriers exist including but not limited to: a lower than required retrofitting rate, insufficient retrofitting scope, and systemic construction sector challenges, which may jeopardise achieving this objective. To fulfil the UK's goal of decarbonising its housing stock, substantial changes must be implemented.

[Transform-ER](#) ([Transform.Engage.Retrofit](#)) is a game-changing, consortium-led project funded by Innovate UK that's tackling the retrofit industry's biggest barriers to achieving scale, from rising costs and underperformance issues to poor collaboration.

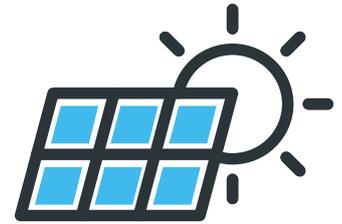
13 industry leaders (see below) are collaborating to create a cohesive, industrialised sector that uses a standardised end-to-end process to deliver high-performance, cost-effective home improvement solutions. The aim is to enable a retrofit sector that can deliver one million home upgrades every year by 2030.

The consortium will use the Demand-Develop-Deploy structure established during the [Construction Innovation Hub](#) to concurrently create new deployment and contract approaches, streamline accreditation processes, prototype products and kits-of-parts, develop digital pipeline tools and a scalable finance mechanism, foster culture change and form a Retrofit Rulebook.

The result? A new industrialised retrofit system and marketplace that upgrades homes and improves lives - open to existing and new delivery partners - tested and ready to launch in 2025, alongside a wealth of learning to be shared widely with the industry.



Executive summary



The UK's housing stock is in a critical state, characterised by poor energy efficiency and unacceptable living conditions. To achieve a notional benchmark of EPC C rating in all homes by 2035, national retrofitting rates must increase sixteen-fold.

Reducing carbon emissions from the housing stock is essential to meet national net zero carbon targets. However, with current methods, supply chain capabilities, and the present appetite of building owners, the UK will fail to meet these targets. A paradigm shift is therefore required to accelerate the change in industry.

Based upon housing survey data from all UK nations, it can be estimated that roughly 50% of the UK housing stock is still rated at band D or lower. UK homes with the lowest EPC ratings are disproportionately represented across fuel poor homes, and improving the energy efficiency of homes is the most effective way of tackling fuel poverty in the long term.

Government funding schemes have started the process of retrofitting the UK housing stock, achieving around 4.1 million energy efficiency measures, saving over 60 MtCO₂ of lifetime carbon, but only since ECO4 was introduced in April 2022 has whole-house retrofit been adopted as a strategy.

To illustrate the market potential, this report estimates that for non-cavity wall dwellings in the UK, industry needs to produce and install an estimated **810 million m²** of internal/external insulation products for this one segment of the retrofitting market alone.

Retrofit is currently achieving around £1bn worth of delivery per year. The Transform-ER consortium believe that the whole market potential could be valued in the order of £20-60bn per year.

Evidence shows that current methods are simply unable to achieve the volumes required and thus the need for retrofit at increased scale is undeniable.

Clear guidance is required on how to achieve retrofit at scale, together with credible demonstration that new delivery models are feasible in the real world. To better envision the future of retrofit, we need to understand the key barriers to scalability.



Transform-ER believes that the whole retrofit market potential could be valued in the order of £20-60bn per year.

Barriers include:

- an underdeveloped supply chain in the UK
- stakeholders' low risk appetite
- limited retrofitting capability and capacity
- workforce and skills shortages
- lack of industry standardisation, and;
- the absence of proven delivery models, including financing.

The Transform-ER consortium and its key work streams aim to overcome these barriers by learning the lessons of the Transforming Construction Challenge (TCC), that is, to accelerate the shift in construction in the UK towards manufacturing and digital processes.

This is underpinned by adopting the DEMAND-DEVELOP-DEPLOY framework defined in the Construction Innovation Hub's Product Platform Rulebook, the hub being the largest project funded within the TCC.

Through adopting the core principles of the TCC, moving towards a Manufacturing-Led approach (including platforms/product platforms, systems engineering, and developing interoperable kits-of-parts), mass customisation can be achieved. This unlocks customised and personalised designs at a cost near mass production.

Further to mass customisation, the benefits of adopting this approach include increased productivity, greater quality control and assurance, and applying digital technologies to further streamline the retrofit process. A Manufacturing-Led approach unlocks finance options through guarantees of functional performance and factory levels of quality.

As we approach the final six months of Transform-ER's Innovate UK funded phase, the lessons learnt from the project will be written up and captured in the project's [Retrofit Rulebook](#). This will provide clear guidance to other industry actors seeking to understand how to reach retrofit at scale.

The UK's big retrofit barriers



An underdeveloped supply chain



Stakeholders' low risk appetite



Limited retrofitting capability and capacity



Workforce and skills shortages



Lack of industry standardisation



Absence of proven delivery models, including financing

Stakeholders

Transform-ER has a far-reaching spectrum of stakeholders invested in its success, however the following key stakeholders have been identified (Figure 1):

1. Clients - e.g. London Boroughs for Social Housing. Define the Need helps clarify what manufacturing / platform approach is required for achieving retrofit at scale, and the benefits of this in working with a new delivery model such as Transform-ER.

2. New entrants to the retrofit market - e.g. manufacturers, professions (e.g. PAS roles) or architects. Illustrating the size of the problem, why transformation is required, how transformation can be achieved through a manufacturing/retrofit at scale delivery model, and insights into some of the market potential.

3. Government Departments - How can retrofit at scale be delivered by new delivery models such as Transform-ER as part of a procurement framework, and why this is so essential to the health and environmental wellbeing of the country?

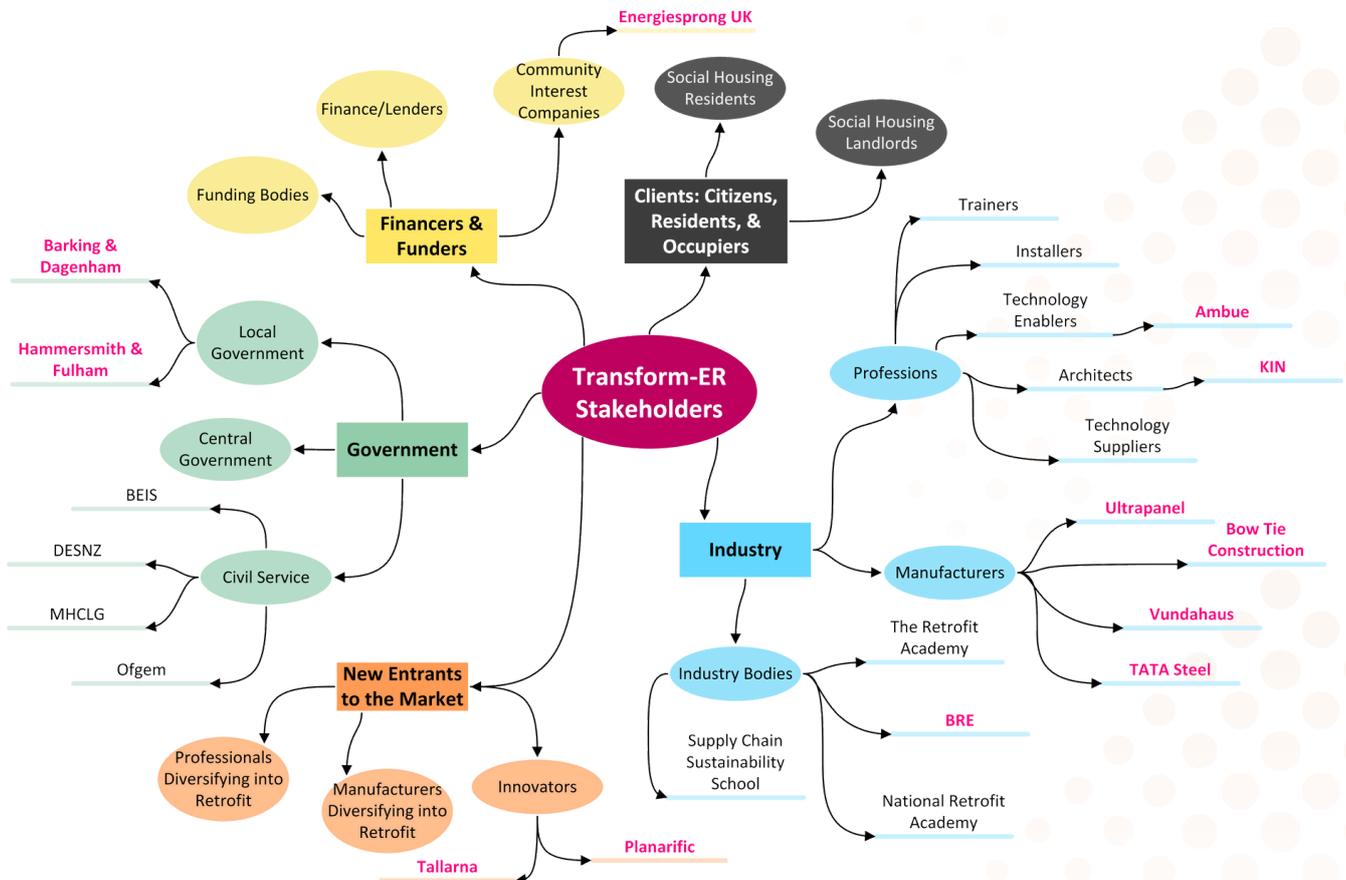


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Abbreviations

BAU	Business as usual
BE	Built environment
BEIS	Department for Business, Energy and Industrial Strategy
BRE	Building Research Establishment
CCC	Climate Change Committee
CIC	Community Interest Company
CLC	Construction Leadership Council
COP	Coefficient of Performance
DEA	Domestic Energy Assessors
DESNZ	Department for Energy Security and Net Zero
DLUHC	Department for Levelling Up, Housing and Communities (Ministry of Housing, Communities and Local Government as of 2024)
ECO	Energy Company Obligation grant
EEM	Energy efficiency measure/s
EER	Energy efficiency ratings
EHS	The English Heritage Society
GCB	Green Construction Board
GWh	Gigawatt hour
HVAC	Heating, Ventilation and Air Conditioning systems
IEA	International Energy Agency
LETI	Low Energy Transformation Initiative
MEES	Minimum Energy Efficiency Standard
MHCLG	Ministry of Housing, Communities and Local Government
Mm²	Million metres squared
MtCO₂e	Million tonnes of carbon dioxide equivalent
NIHCS	Northern Ireland House Condition Survey
NZ2050	Net Zero 2050 commitments
PRS	Private rented sector
RR	Retrofitting Rate
SAP	Standard Assessment Procedure
SCOP	Seasonal Coefficient of Performance
SHCS	Scottish House Condition Survey
TCC	Transforming Construction Challenge
UK	United Kingdom
WHCS	Welsh Housing Conditions Survey

Background

As a response to climate change and its impacts on the UK economy, human health and ecosystems, the Government committed to reducing emissions by 78% by 2035 compared to 1990 levels, and to net zero by 2050 ([BEIS, 2021](#)).

To do so, the UK government is implementing a range of strategies such as setting reduction targets and carbon budgets across all sectors. These are defined by pathways and recommendations set out by the Climate Change Committee (CCC), a non-departmental body formed under the Climate Change Act (2008), which advises the UK Government on tackling climate change.

The built environment sector is faced with challenging objectives requiring fundamental and systemic changes in the years ahead to meet the committed targets on time.

Current emissions attributable to the built environment

The UK's Built Environment (BE) emissions are divided across several "sub-sectors" defined by the CCC (UKGBC, 2021). The UKGBC's Net Zero Whole Life Carbon Roadmap captures all BE emissions under a common umbrella in order to determine the BE footprint and identify specific actions (UKGBC, 2021).

According to this document, the BE was responsible (had direct control) for 25% of total UK emissions in 2018 (surface transport excluded). The existing housing stock made up the largest share (48%) of the UK BE's emissions for the same year, of which over 62% were produced by space heating generation by fossil fuel boilers, mainly, (UKGBC, 2021) (Figure 2).

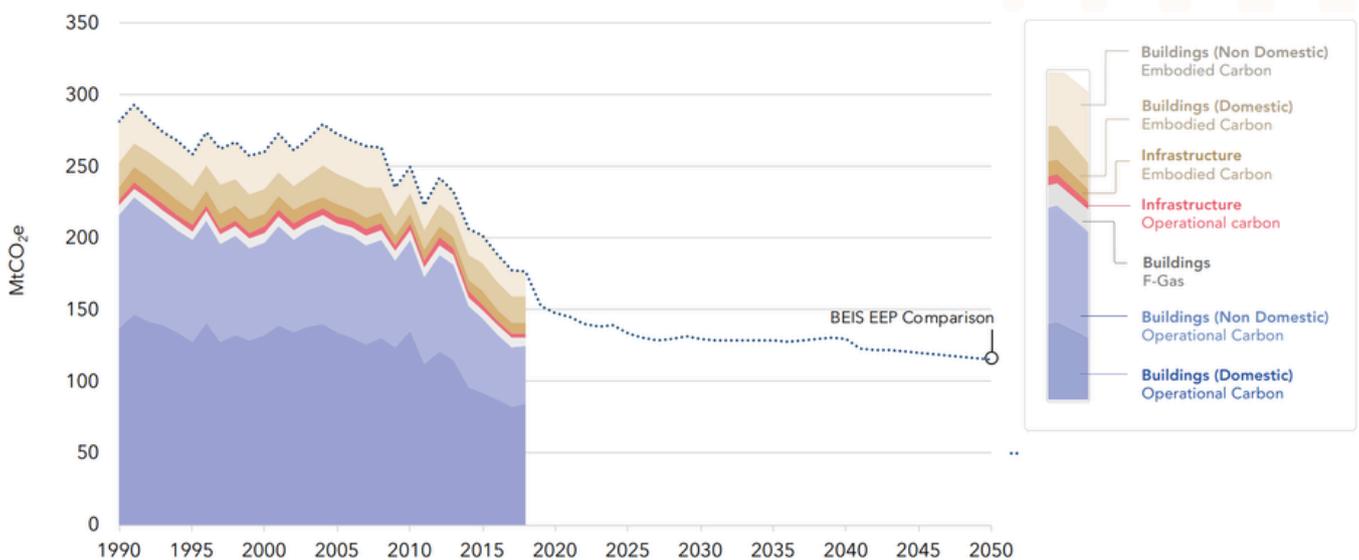


Figure 2: Historic (1990-2018) built environment emissions (excluding transport), with business-as-usual projections applied (UKGBC, 2021).

More than three-quarters of household energy demand is for space heating and hot water (IET, 2020), and currently around 80% of household heating is satisfied by gas or oil boilers (UKGBC, 2021).

The high demand and environmental impact of the energy generated by fossil fuel boilers to satisfy the UK housing demand means decarbonising and reducing the heating demand is the primary strategy to decarbonise the BE sector.

This can be achieved by:

- Decarbonising the energy source by moving away from fossil fuel heating e.g. gas boilers.
- Reducing the demand by increasing the energy efficiency of the housing stock.
- Continuing to decarbonise the electricity supply i.e. the national grid.

Emissions reduction target

According to the CCC 6th Carbon Budget (CCC, 2020), meeting the UK's net zero 2050 target involves the full decarbonisation of buildings' direct emissions (i.e. from running of the building, for example, heating and electricity), while the emissions from manufacturing and construction of buildings will have their own residual emissions budget.

If the sector continues a business-as-usual (BAU) approach (i.e. making no further interventions beyond those already in place), a reduction of only 60% compared to 1990 emission levels would be achieved by 2050 (UKGBC, 2021). The reductions of 30% experienced in the BE's emissions since 2010 are attributable to the decrease in operational emissions of buildings (UKGBC, 2021). However, the reason behind this is the decarbonisation of the national electricity grid, rather than the energy efficiency of buildings.

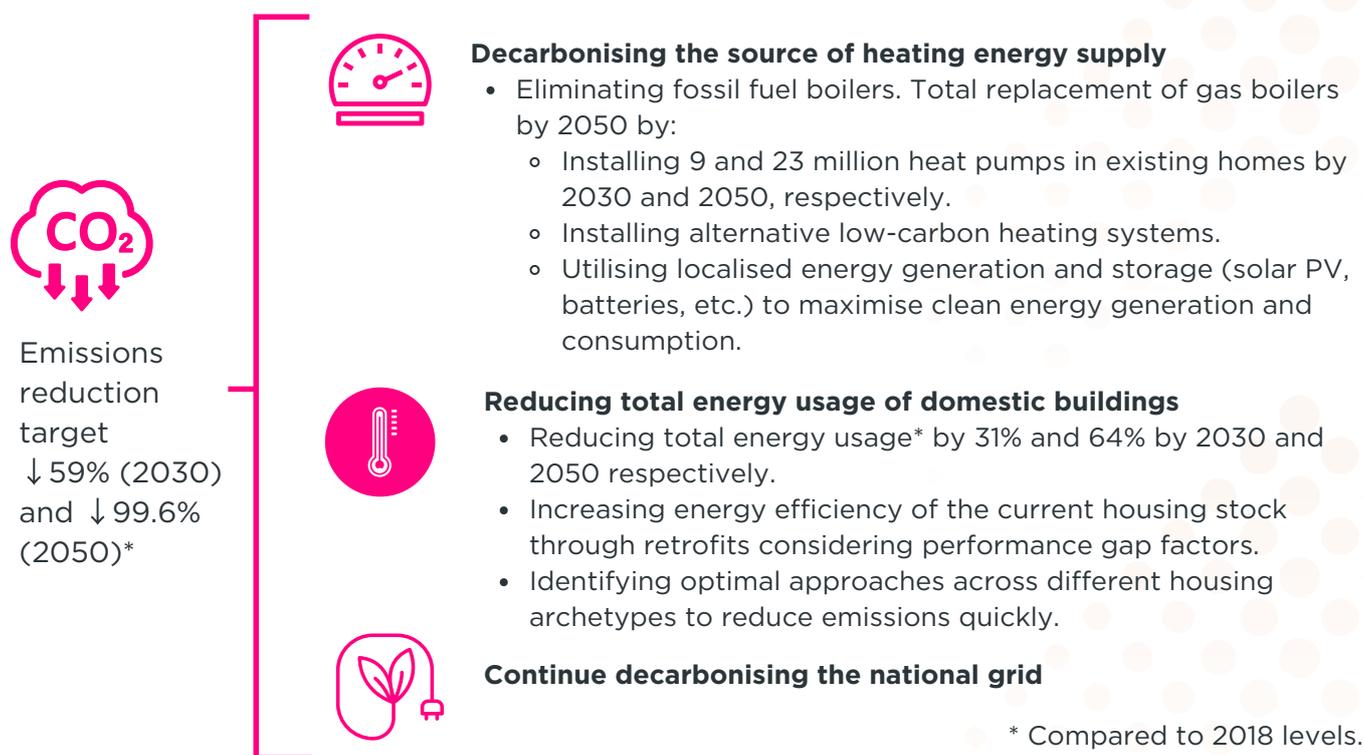


Figure 3: Targets to meet the CO₂e reduction targets according to UKGBC (2021).

To meet net zero targets, emission reductions must accelerate (Climate Change Committee, 2023). The CCC sets a reduction of 43% of buildings emissions (30% fall on energy demand) by 2035.

Operational carbon due to domestic buildings are expected to be cut to 35.1 MtCO_{2e} (-59%) and to 0.3 MtCO_{2e} (-99.6%) by 2030 and 2050 respectively, taking 2018 as a baseline (UKGBC, 2021).

Figure 3 outlines the targets that need to be met by the three simultaneous strategies to reduce the operational carbon of buildings. These forecasts underline the vast reduction in energy consumption by the existing building stock needed to get on track on the net zero targets.

The importance of retrofitting the UK housing stock

Over the last five to ten years, many organisations have published reports outlining the importance of retrofitting the UK housing stock as a solution to reducing emissions and increasing comfort, as well as defining the challenges and barriers to ramping up retrofit to the scale and at the speed required.

This includes:

- The Royal Institute of Chartered Surveyors (RICS) ([Russen, 2024](#))
- Low Energy Transformation Initiative (LETI) ([LETI, 2021](#))
- UK Green Building Council (UKGBC) ([Wheeler, et al., 2021](#))
- The Committee on Climate Change (CCC) ([CCC, 2019](#))
- The Connected Places Catapult ([Connected Places Catapult, 2020](#))

- The Energy Systems Catapult ([Hargraves, 2022](#))
- The Institution of Civil Engineers (ICE)
- The Institution of Engineering & Technology (IET) ([IET, 2020](#))
- Passivhaus Trust ([Passivhaus Trust, 2022](#)).

As well as government departments such as:

- Department for Energy Security and Net Zero (DESNZ) (DESNZ, 2024)
- The Department for Business, Energy, and Industrial Strategy (BEIS) (BEIS, 2020).

The need for retrofit at scale is clear from the volume of evidence. What is now required is guidance on how to implement this at scale, while demonstrating that delivery models are feasible.



Retrofitting to reduce the energy demand

In its current state, the National Grid does not have peak power capacity to satisfy demand if domestic heating were to switch over to electric sources (i.e. heat pumps) (Passivhaus Trust, 2022).

Additionally, other sectors (such as automotive) are transitioning to electrified energy systems, thus increasing the demand further.

Therefore, there is a need for decreasing the energy demand from homes due to:

- Limited low-carbon energy mix from the national grid.
- All sectors transitioning to use low-carbon energy from the grid (e.g. development of electric vehicles).
- Hydrogen technologies unlikely to be appropriate for domestic heating in the short term.

- The current peak heating load covered by gas (170 GW) is greater than the current electric grid capacity (100 GW).
- Switching the UK's ~30 million existing homes from gas to electricity without reducing demand through energy improvement works would add an additional peak demand of 68GW, which the national grid would need to supply during peak times.¹

Considering the large impact heat generation has on the energy demand of UK homes, and that 80% of our current housing stock will still be in use by 2050 (UKGBC, 2024), increasing the thermal efficiency of homes is key to reduce the energy demand.



Retrofitting UK homes is one of the greatest opportunities to reduce the nation's carbon emissions while modernising the housing stock, improving citizens' quality of life and reducing costs associated with health issues arising from energy-inefficient homes.

¹ If this demand is met using Air Source Heat Pumps (ASHPs) with a Coefficient of Performance (COP) of 2.5.

Retrofitting to upgrade the current UK housing stock

The UK has one of the oldest dwelling stocks in Europe.

Old buildings often rely on inefficient heating systems and are either poorly insulated or not insulated at all (BRE Trust, 2020), leading to high energy consumption, high carbon emissions and health issues for occupants due to exposure to extreme temperatures (hot and cold), and excess moisture leading to mould.

Houses having at least one category 1 hazard such as damp and mould are almost nine times (26%) more prevalent in pre-1919 homes compared to those built after 1980 (3%) (BRE Trust, 2020).

There are subtle differences across the UK nations regarding the breakdown of the dwelling stock age. For example, Northern Ireland has a relatively new stock with 40.4% of dwellings constructed post-1980 and only 10.5% pre-1919 in comparison to Wales which is 25% post-1980 and 26% pre-1919.

In both cases, there is a notable proportion of properties that will be, due to their age, susceptible to hazards associated with older dwellings.

The ageing nature of the UK's housing stock results in many households suffering from fuel poverty whereby high energy bills relative to income prevent adequate heating of their homes.

The most recent data, while not strictly comparable across nations due to variations in methodology, indicate that 13% of households in England, 20% in Scotland, 14% in Wales and 24% in Northern Ireland are experiencing fuel poverty (House of Commons Library, 2024).

Retrofitting can lower energy bills through improved efficiency, but it needs to be financially viable, de-risked, delivered to quality, and accessible for all.



The UK experiences 10,000 deaths a year attributed to cold homes (Seaton-O'Connor, et al., 2024) and a further 2,000 due to overheating in homes (HM Government, 2017), costing £1.4 billion per year to the NHS, only in England.

(BRE Trust, 2020)

Retrofitting rate targets

In this project, the retrofitting rate target refers to the percentage of existing residential buildings to be retrofitted within a certain timeframe to achieve compliance with climate goals.

The International Energy Agency (IEA) established the global average retrofit rate (RR) target of at least 2.5% of existing homes upgraded to net zero per year by 2030, this is currently estimated to be lower than 1% per year globally (IEA, 2021).

In countries with old building stock such as the UK, this target can be higher, (Kilgour, et al., 2022). The IEA highlights the need to retrofit to net zero levels up to 50% and 85% of existing buildings by 2040 and 2050 respectively.

The UKGBC estimates all homes rated EPC band D or below² would need to be upgraded to at least EPC C before 2035, while all remaining homes would need to be upgraded by 2050 (UKGBC, 2024).

Therefore, according to the EPC data obtained from UK housing surveys, more than 1.4 million homes would need retrofitting annually before 2035, then 0.62 million annually between 2035-2050.

This exceeds the average 2.5% RR and equates to almost 7,300 homes per day by 2035, and then 1,500 homes per day thereafter until 2050 (assuming a five working day week and that homes do not need to be revisited), see Figure 4 below for further details.

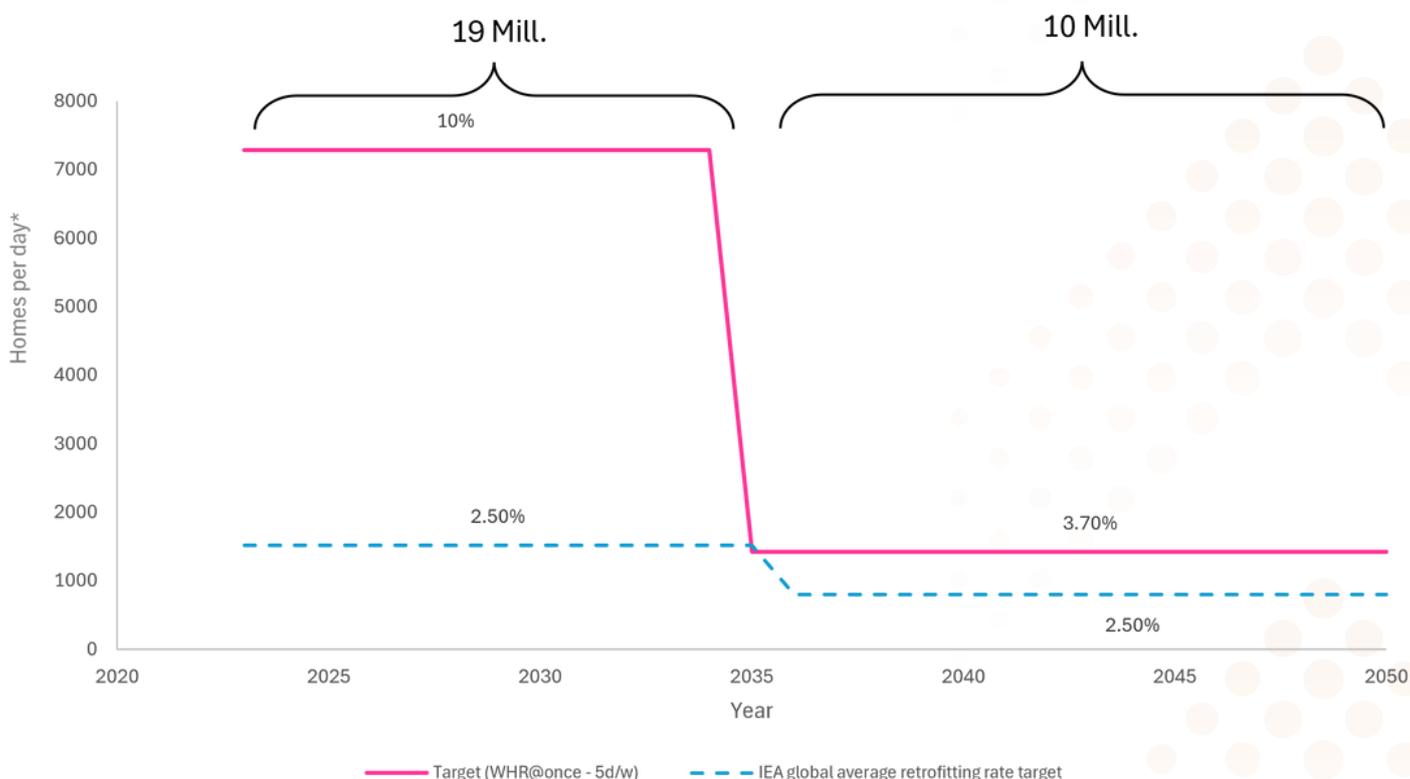


Figure 4: Retrofitting rate target based on UKGBC estimation and current targets.

² Based on the latest housing survey data in 2024 (EHS, 2024) (NIHCS, 2016) (WHCS, 2017) (SHCS, 2022), we estimate this number to be 15.1 million homes.

Key barriers to retrofit

Several key barriers to retrofit exist (Lewis & Smith, 2014; Traynor, 2022).

These include:

1. Systemic construction sector challenges: The UK construction sector faces challenges such as the shortage of skilled workers, inefficiencies in project management, and supply chain bottlenecks.

There is a lack of skills and knowledge within industry regarding [whole-house retrofit](#), from tradespeople, to surveyors, and designers. The Construction Industry Training Board (CITB) has calculated that an additional 400,000 skilled workers are needed for retrofit, and by 2028 the UK needs 86,000 project managers (such as Retrofit coordinators), 27,000 building envelope specialists, 59,000 plumbers and HVAC workers (CITB, 2021).

The Construction Leadership Council (CLC) lays out the skills and competencies required to reach retrofit at scale in their [Roadmap of skills for net zero](#), highlighting the future requirement for capacity and capability in the UK workforce for domestic retrofit (CLC, 2024).

2. Public awareness and engagement: Many homeowners and landlords are not fully aware of the benefits of retrofitting or of the financial assistance that is available to support such activity. There is a need to improve public awareness and engagement to increase demand for retrofitting. Without widespread buy-in, targets will be difficult to achieve.

Additionally, the general public are largely unaware of the impact that heating our homes has on the environment, (Smallbone, 2012).

3. High costs and funding gaps: Fundamentally, the cost of whole-house retrofit is unattainable for those with low disposable income, particularly with high upfront costs and long payback periods (Lewis & Smith, 2014; Traynor, 2022).

Estimates suggest it could cost £250 billion or more to bring the UK's building stock to net zero standards (CCC, 2020).

Energiesprong UK highlight this issue further:



“Lack of scalable private finance remains one of the biggest barriers to action in the social housing sector, with landlords facing a £90+ billion³ funding gap for net zero. Many have no way of raising the required capital off-balance sheet.”

(Energiesprong UK, 2024)

Many households, especially low-income ones, cannot afford the upfront costs. They require funded solutions - be that through government support/subsidies or private finance.

³ Recent updates suggest this could be closer to £104 billion

At the same time, projects need to deliver immediate bill reduction to building owners/occupiers while also meeting funders' investment criteria, if they are to be deemed worthwhile. Overcoming the confidence gap in projects' financial benefits is just as important as overcoming the upfront cost barrier.

4. Policy and coordination issues:

While the UK government has implemented several funding schemes (e.g., Green Homes Grant), there is a need for a cohesive, long-term strategy that includes better coordination between national and local governments, industry stakeholders, and homeowners.

Consistent programmes that focus on deep retrofit strategies and retrofitting plans are needed. This is highlighted by the number of different schemes over the past 10 years, all with different objectives and retrofitting strategies, for example:

From 2013 to the end of 2023, around 4.1 million energy efficiency measures were installed in 2.7 million properties in Great Britain through various government support schemes:

- Energy Company Obligation (ECO)
- Green Deal (GD) Framework Green Homes Grant Vouchers (GHGV)
- Local Authority Delivery (LAD)
- Home Upgrade Grant (HUG)
- Social Housing Decarbonisation Fund (SHDF)
- Great British Insulation Scheme (GBIS).

(DESNZ, 2023)

Ideally, one standardised national funding scheme would be rolled out at scale across the UK, with consolidated retrofitting goals such as whole-house retrofit.

As well as the funding schemes, clear policies are required, for example outlining a need for the upgrade of homes via retrofit, as well as standards governing quality control/quality assurance of installation.

5. Consumer perceptions:

Consumer barriers to energy efficiency retrofits in UK homes include difficulty reaching vulnerable groups, low awareness, and lack of interest. Retrofits are often seen as less attractive than other home improvements, with concerns about workmanship, property damage, and complex technologies.

Fears of lifestyle disruptions and doubts about long-term investments further deter adoption, especially among elderly homeowners.

6. Supply chain: The implementation of energy efficiency retrofits is challenging due to a fragmented and underdeveloped supply chain lacking coordination and integrated solutions. The unique characteristics of each property requires comprehensive surveys, adding complexity and cost, while the absence of standardised definitions and holistic design approaches further complicates retrofit projects.

The predominance of small and medium-sized enterprises, that often struggle with resources and capacity, leads to unequal coverage and implementation of energy measures across regions. Additionally, a lack of long-term strategic planning and trust among industry stakeholders hampers efforts to improve building performance and efficiency on a national scale.

7. Practical installation issues: Practical barriers to energy efficiency retrofits in UK homes include technical challenges due to unique property features and the lack of universal solutions. Disruptions like mess, noise, and the need for temporary relocation deter homeowners, especially with intrusive measures. Issues like asbestos, space constraints, and incomplete property information complicate installations, while time limits and high costs further hinder projects.

Quality assurance, split responsibilities, and concerns over changes to a property's appearance also contribute to resistance. The lack of a clear integrator role as well as the lack of clarity of roles and responsibilities across multi-disciplinary teams, involving numerous organisations can result in gaps in delivery of retrofit projects (BEIS, 2021).

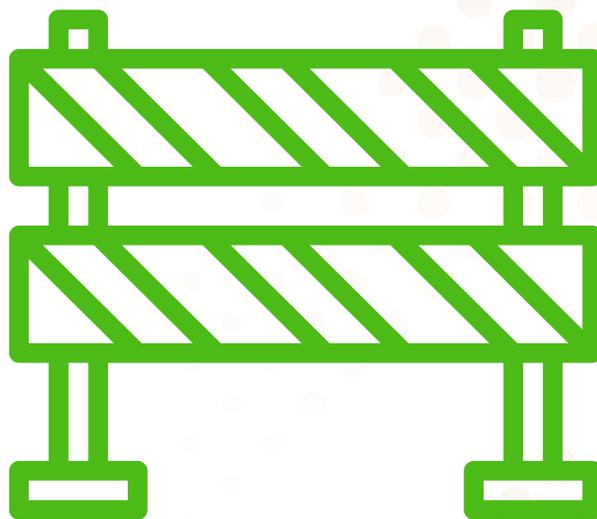
Not having the ability to coordinate the multiple parties involved with retrofit projects is a significant barrier to homeowners and occupiers. Although PAS 2030 and PAS 2035 do seek to define retrofit roles and responsibilities.

8. Performance: Performance barriers to energy efficiency retrofits in UK homes stem from a gap between estimated and actual performance due to measures not working as intended, poor installation, and occupants not understanding how to operate and maintain new technologies.

Incorrect advice from assessors or installers and the selection of unsuitable or inefficient products further exacerbate this issue.

9. Influence and awareness:

Currently, there are too few successful examples and too many pilots that fail to produce concrete solutions. Deployment, publicity, and expectations surrounding new technologies need to be carefully managed as poor examples and negative publicity could hinder progress across the entire industry. A lack of influential and credible pioneers will stall wider uptake of energy efficiency measures.



The future of retrofitting: the Transform-ER approach

Why do we need transformation?

The problem statement for the UK retrofitting targets revolves around the need to meet ambitious climate goals, improve energy efficiency in ageing building stock, and address various socio-economic challenges. From the background statements, retrofitting the UK housing stock is a national need.

However, with current retrofitting rates and traditional BAU, the targets are not achievable; especially considering the shortage of skilled labour and the supply chain challenges to meet the ambitious retrofitting targets.

The technologies and solutions to improve building energy efficiency are already in place – what is needed now is large-scale delivery at an accelerated rate. Achieving this requires national and local cooperation to speed up retrofitting. This will involve rolling out funding strategies that guarantee equitable access to resources and eradicate fuel poverty, driving policy reforms, minimising public inconvenience, and ensuring retrofitted buildings deliver long-term energy savings.

Governments are making efforts to economically support households to act and improve the efficiency of their homes. However, these measures are insufficient and are not planned ‘as a whole’. For instance, in the UK, only the [ECO4](#) funding scheme adopted a whole-house retrofit approach (DESNZ, 2024).

The acceleration of home retrofitting is clearly desirable; however, it must be carried out with the required quality to ensure it does not cause further damage or lead to higher costs in the future (e.g. from bills, maintenance, or further replacement). It is essential that improvements are designed and implemented according to a plan to meet clear and achievable targets with minimal disruption, especially in cases of occupied homes.

We need innovative ways to address the retrofit challenge. This requires creating new solutions, a focus on supply chain collaboration, relying on Manufacturing-Led strategies, finding scalable ways to fund projects, and staying flexible to apply creative ideas step-by-step.



What does transformation look like?

Transform-ER is a novel consortium funded by Innovate UK to tackle the multiple barriers to retrofitting homes.

Thirteen industry-leading partners have teamed up to catalyse the transformative change that is required to enable the rapid deployment of high-quality, cost-effective and performance-guaranteed retrofit solutions, that are financed under a shared savings model.

The Transform-ER approach will enable a systemic change to tackle multiple, intertwined challenges. Transform-ER aims to accelerate several market mechanisms simultaneously by launching a new system and marketplace for retrofit, open to both existing and new delivery partners.

It will achieve this by:

- **Developing new digital tools** and approaches to assess portfolios, categorise archetypes, aggregate demand, quantify property retrofit performance risks, and enable standardisation.
- **Enabling the adoption of industrialised solutions and interoperability rules** to facilitate the integration and implementation of products from different manufacturers as a kit-of-parts.
- **Facilitating the adoption of robust funding mechanisms** to alleviate the gaps between current government subsidies and private financing.

- **Creating a Community Interest Company (CIC)** to provide a fair and structured 'profit for purpose' market vehicle. This vehicle will unlock new income streams for retrofits, which can be financed through a shared savings model, and deliver a standardised contract structure for deployment. Performance insurance will be central to this, guaranteeing outcomes for both residents and investors, allowing private finance to scale social housing retrofits.
- **Streamlining accreditation routes** and prototyping products and kits-of-parts, while defining interoperability standards to cost-effectively meet demand.
- **Forming a Retrofit Rulebook** to document project activities as case studies and provide clear guidance for other industry players and those looking to join the retrofit movement.



Unlocking finance

This section was written with Transform-ER partner Tallarna.

Why is finance a priority for Transform-ER?

Finance is consistently cited as one of the biggest barriers to action for large-scale retrofit. As such, it is a fundamental task of Transform-ER to try to unlock some of the trillions needed to deliver net zero.

Grants and existing budgets have so far proven insufficient for housing associations, homeowners, and private landlords to deliver building decarbonisation at scale. Now is the time for private finance to take the lead. Already, three quarters of global energy investment is driven by private and commercial sources (IEA, 2024) with global investment in clean energy technologies and infrastructure projects exceeding \$2 trillion in 2024, a record high (IEA, 2024)

As such, while there is no shortage of private finance for projects generally, the challenge for building owners is how to access finance for their specific retrofits. To do that, building owners must structure their projects in a way that aligns with funders' investment criteria and risk appetite.

Although this report explores retrofit across all tenures – helping identify systemic issues in scaling projects – Transform-ER's approach is to “start with social housing: private market comes later” (Energiesprong, 2017).

The reasons for this are twofold.

Firstly, starting with social housing facilitates energy upgrades for those least able to afford such improvements. Secondly, social housing provides the aggregation and scale the private sector needs to attract new market entrants who can address the systemic challenges raised in this report.

Why is traditional finance not enough for social housing retrofit?

The social housing sector is facing a £104 billion bill for net zero (Crown Commercial Service, 2023). Currently, announced grants will only meet £9.5 billion of the costs (SHDF, Warm Homes, ECO, HUG, LADS, GHNF etc.⁴). While some of the costs can be covered by landlords' existing budgets and traditional forms of finance, the rest requires an alternative approach.

Existing budgets and traditional forms of finance are insufficient for delivering retrofit at scale for three core reasons:

1. Outstanding debt: Landlords' debt represents 46% of their total balance sheet asset value (Savills, 2021), with S&P estimating that the social housing sector will have £116 billion of outstanding debt by 31st March 2025 (S&P Global, 2023). This high amount of outstanding debt limits landlords' ability to borrow more money on their balance sheets.

2. Loan covenants: When landlords take on debt, they must agree to a set of loan covenants. These are promises that a landlord makes to the debt provider.

One of the key covenants is landlords' EBITDA MRI Interest Cover Ratio (Earnings Before Interest, Tax, Depreciation, Amortisation, Major Repairs Included).

⁴ Social Housing Decarbonisation Fund (SHDF), Energy Company Obligation (ECO), Home Upgrade Grant (HUG), Local Authority Delivery (LAD), Green Homes Grant Vouchers (GHGV) respectively are all government funded grants.

This ratio indicates the level of surplus generated by a landlord compared to interest payable on their balance sheet.

Each debt provider has certain ratio targets that landlords must hit, otherwise they are in breach of their loan covenants and their debt may be recalled. The sector is currently not in a good position with its loan covenants.

For the first time since the 2008 financial crisis, social housing landlords' average EBITDA MRI Interest Cover Ratio is below 100% (Social Housing, 2025). This means landlords are now paying more in interest than they are earning (when major works' costs are deducted) on an annual basis.

A key challenge posed by landlords' loan covenants is that retrofits are classified as "Major Repairs". In other words, spending on retrofits counts against their EBITDA MRI Interest Cover Ratio (National Housing Federation, 2022). This is true even if the money comes from grants or their own existing budgets. This puts landlords in a no-win situation as it means they cannot fund projects, but simultaneously they are required by the government to upgrade their homes to EPC C by 2030 (Inside Housing, 2024).

3. Terms of traditional finance: Most debt is securitised against residents' homes and has a 5-10-year loan term.

This average term is shorter than the cash flows generated by retrofits – meaning projects' payback period exceeds the debt repayment period. At the same time, given the level of landlords' existing debt, securitising more debt against residents' homes is simply too high a risk when the penalty for default is repossession.

As a result of the above, the sector only has around £7.4 billion of debt capacity and £2.8 billion of refinancing capacity for net zero and other major works (Savills, 2021). Debt capacity includes how much of landlords' internal budget they can spend given their loan covenants. Refinancing capacity is how much finance can be raised by renegotiating existing debt.

In light of the above, the sector is collectively facing a c.£104 billion shortfall for net zero (Crown Commercial Service, 2023).

What does transformation in finance look like for social housing retrofit?

To deliver retrofit at scale and bridge this funding shortfall, social housing landlords need to access private finance that is not raised or securitised against residents' homes, is long-term, and is off-balance sheet. For funders to agree to this, they need certainty in their returns.



“Overcoming retrofits’ financial uncertainty for funders and residents is key to unlocking private finance. By uniting stakeholders behind shared, de-risked outcomes, insurance and structuring creates the conditions in which decarbonisation at scale can, and is, happening.”

(Tim Meanock, CEO Tallarna, 2025)

The solution lies in project finance supported by insurance and structuring. Project finance is where finance is raised and repaid against the predicted value delivered by a project instead of against residents' homes. In solar and storage projects, for example, value used to raise and repay project finance could include revenue from selling excess energy from installed solar panels to the grid and the fee residents' pay for buying discounted energy from installed solar panels and batteries, among others.

Making project finance long-term and off-balance sheet requires insurance and structuring (Tallarna; Baringa, 2025). Insurance can guarantee the technical performance and resulting economic outcomes of a retrofit for up to 30 years. This matches the payback period of many measures, helping funders become comfortable lending over longer timeframes.

In terms of off-balance sheet treatment, insurance enables funders to invest in a third-party structure called AssetCo without providing a fund guarantee. AssetCo is an entity created and owned by the funder to manage a specific project (CTVC, 2024). AssetCo takes on the legal responsibility for a project's performance, limits landlords' capital contribution to works, is the owner of the installed clean energy technologies, and manages the energy assets' maintenance costs. This helps large-scale projects align with the International Financial Reporting Standards (IFRS) 16's definition of off-balance sheet treatment.

As a result, landlords can action projects without putting a strain on their existing debt and have the majority of their CapEx externalised through project finance.

Taken together, insurance and structuring also help lower landlords' operating expenses under their loan covenant definitions as it externalises the cost of major works. This is key to boosting landlords' EBITDA MRI Interest Cover Ratio (Tallarna, 2023).

However, if retrofits are to meet their social purpose, they must also leave residents better off from day one (Tallarna, 2023). For many ESG-focused funders, resident outcomes are a key part of their investment criteria. A shared savings model can be leveraged alongside project finance to ensure residents' benefits. A shared savings model is where some of a project's value is used to fund the works while the balance stays with residents on day one. Insurance can also be used to defend these savings. For a solar and storage project, residents' savings can be achieved by pricing residents' fee for purchasing energy from installed solar panels and batteries at a discount to the energy price cap.



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How does finance work within a Manufacturing-Led approach?

The consortium’s Manufacturing-Led approach is informed by the above understanding of how large-scale private finance can be introduced and what this means for new technologies.

For example, as new retrofit product innovations progress through the Technology and Manufacturing Readiness Levels (TRL & MRL), they demonstrate increasing functionality and production. This higher production rate lowers the cost of the technologies. This makes them more financeable. At the same time, technologies’ deployment will deliver a bank of real-world data that enables product performance and its outcomes to be insured. This insurance, coupled with structuring, lets project finance externalise the majority of the costs of retrofit and unlock at-scale projects.

Figure 5 visualises how retrofit products can progress through TRL and MRLs to unlock private sources of finance.

“Driving product and process innovation and supply chain collaborations to establish a new construction manufacturing sector for attractive, affordable, financeable net zero energy refurbishments in the UK and France using frontrunner social housing organisations. The result should be: Quality and assured performance, Affordability and Desirability.”

(Energiesprong, 2017)

Manufacturing-Led retrofit can catalyse the development of product and process innovation and therefore build the assurances and guarantees required to unlock greater levels of private finance.

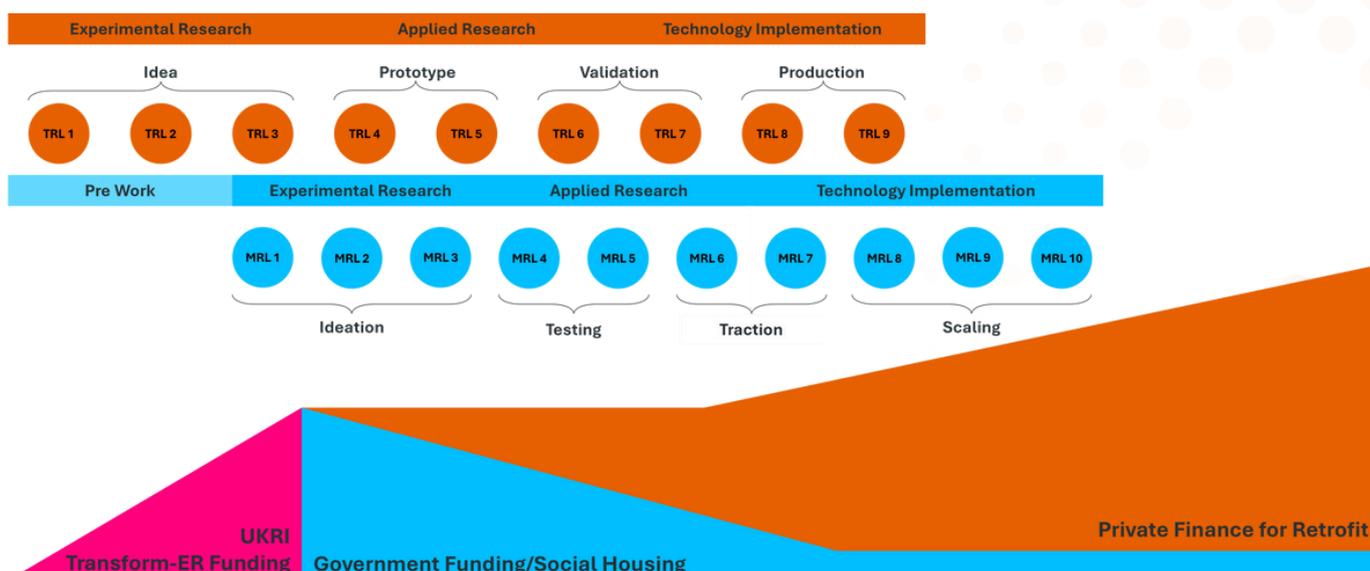


Figure 5: How Manufacturing Readiness Level (MRL) and Technology Readiness Level (TRL) can be linked with government and private finance.

Retrofit at scale: A Manufacturing-Led approach

This section explores some of the key concepts developed under the Transforming Construction Challenge (TCC), which was funded by the UKRI Challenge Fund to accelerate the shift in construction in the UK towards manufacturing and digital processes, the challenge ran from 2018 to 2023.

The Research and Development (R&D) included the adoption of platforms, systems engineering, and interoperable kits-of-parts. These are all inherently linked concepts, aiming to deliver a manufacturing approach for new build government pipeline. These fundamental concepts established in the TCC can also be applied to reach retrofit at scale.

What is a platform?

The term 'platform' is used in both different contexts and at varying degrees of scale, ranging from specific products to solutions that span multiple industries. Irrespective of this diversity, platforms share several common features:

- A set of low variety common assets shared by a set of products. These 'common assets' are typically physical components, but may also include repeated processes, knowledge and relationships. The common assets are replicated multiple times, enabling platform owners to gain competitive advantage by enhancing production or delivery efficiency.
- A complementary set of peripheral components that exhibit high variety. The use of interchangeable peripheral components results in a diversity that creates distinctive offerings to the market.

- A stable interface that acts as a bridge between the stable core and variable peripherals, permitting innovation in both core and peripherals.
- A set of rules/standards governing how components can be integrated.

Strategically leveraging the benefits of commonality, platforms have been successfully applied across a variety of industries to deliver mass customised products, affording customers with choice while maintaining an efficient and effective method of production. (CIH, 2022).



What is a product platform?

Product platforms can be defined as:

- The kit-of-parts associated production processes, knowledge, people and relationships required to deliver all or part of construction projects using a platform approach.
- A product platform provides a stable core which is configured and combined with complementary components (via defined interfaces) to suit a particular project.
- A product platform also includes the processes, tools and equipment required for assembly. Product platforms are therefore not buildings but common components, processes or knowledge, applied to deliver a range of distinct assets (that may range from specific parts to whole buildings) efficiently through economies of scale and scope.

The combination of common, repeatable assets with complementary elements, brought together with standard interfaces, enables a product platform to be extended to produce product families (a group of related products that share common features) that serve a variety of market segments ([Product Platform Rulebook](#), (CIH, 2022)).



Adopting a platform approach for retrofit enables the move towards mass customisation and interoperable kits-of-parts

Why adopt a platform approach?

Adopting a platform approach offers several benefits to the construction industry, including improved productivity, efficiency, and predictability, as well as reduced costs through standardised and repeatable solutions.

The approach also enhances quality control, minimises onsite safety risks, and reduces waste and carbon footprints. Platforms help shift the focus toward continuous improvement and optimisation of both processes and products, while also contributing to social and economic benefits such as stable and inclusive employment in regional manufacturing hubs (CIH, 2022).

How can a platform approach be applied to retrofit?

By encouraging collaboration and innovation within the retrofit market, manufacturers of retrofit products for specific PAS 2030 and PAS 2035 energy efficiency measures can develop standardised, repeatable and de-risked standard details for interfaces.

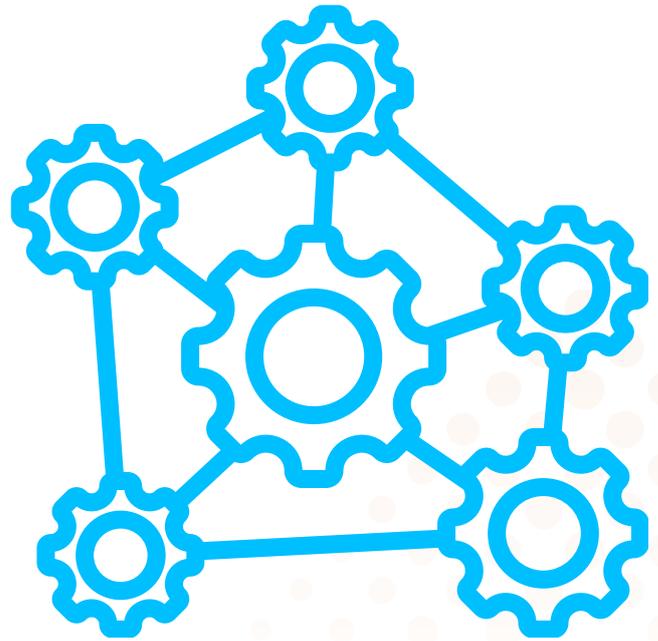
By embedding common repeatable elements such as kits-of-parts, repeatable processes, knowledge and relationships, retrofit manufacturers can adopt a platform approach – to gain the benefits of repeatability, while developing variable product families and product variants with a level of flexibility to meet the needs and requirements of different projects and programmes.

Adopting a platform approach for retrofit enables the move towards [mass customisation](#) and [interoperable kits-of-parts](#).

What is systems engineering?

Systems engineering is a multidisciplinary approach focusing on the design and management of complex systems. This approach emphasises using a structured methodology to establish and understand the interactions between all elements within a system and how they contribute to its function. By considering a system as a collection of interconnected components, it is possible to optimise it for efficiency and efficacy.

In these terms, 'Engineering' and 'Engineered' do not exclusively refer to products and structures but may also be composed of people, services, information, and processes (INCOSE, 2024).



Why adopt systems engineering?

According to a Construction Leadership Council (CLC) and Green Construction Board (GCB) report into the progress made since the Infrastructure Carbon Review (HM Treasury, 2013), "systems thinking" is identified as a key component to achieving meaningful decarbonisation of infrastructure (Green Construction Board, 2021).

The benefits of using this approach for whole-house retrofits are:

- **Enhanced efficiency:** Optimises all systems to work together, maximising energy savings and performance.
- **Cost-effectiveness:** Reduces redundant or conflicting upgrades, ensuring that investments yield the best possible returns.
- **Improved comfort and functionality:** Creates a balanced environment where heating, cooling, lighting, and other systems complement each other.
- **Sustainability:** Promotes the use of eco-friendly materials and technologies, reducing the home's environmental footprint.
- **Reduced risk:** Anticipates and mitigates potential issues through thorough planning and coordination, particularly through pipeline definition to establish future workflow.
- **Scalability:** Facilitates phased or scalable retrofits, allowing homeowners to prioritise upgrades based on needs and budgets.

How can systems engineering be applied to retrofit?

A whole-house retrofit involves improving the energy efficiency and overall performance of a home through various upgrades, such as insulation, heating, ventilation, and air conditioning (HVAC) systems, windows, and more.

In its guidance document for PAS 2080 (Carbon Management in Infrastructure and Built Environment), The Institution of Civil Engineers highlights the need for systems thinking (ICE, 2023):



“The built environment itself comprises a complex system of systems...the concept of systems thinking is a step change for the built environment, driven collaboratively by asset owners, designers, constructors and product/material suppliers... every organisation must align their pipeline of projects and/or programmes of work with the scope and timeline for the net zero carbon transition at the systems level.”

Institution of Civil Engineers

Using systems engineering and systems thinking in this context can lead to more efficient and effective retrofitting processes through the following means:

- **Holistic view of the home as a system:** Instead of viewing each element of a retrofit in isolation, assessing the home as a whole system with a strictly defined goal in mind allows each component to work in the most efficient way to achieve that goal.
- **Leveraging digitally enabled processes:** Using digitally integrated systems enables smooth transfer of information, examples of this include project management, monitoring and performance tracking, and building design specifications, all of which should be centrally managed within an easily accessible database.
- **Leveraging digitally enabled products:** Using the latest digitally enabled products can significantly enhance performance by facilitating data sharing, which optimises the effectiveness of all system components. For instance, Virtual Power Plants (VPPs) enable multiple solar and battery systems to collaborate, benefiting both individual users and the broader system.
- **Integration of subsystems (heating, insulation, windows etc.):** Ensuring interoperability between components within the system ensures that each element can integrate with the wider system without impedance.
- **Energy modelling and simulation:** By simulating various retrofit scenarios and their constituent elements, engineers can find the best combination of improvements that will reduce energy consumption, lower costs, and enhance comfort.

- **Lifecycle consideration:** Systems engineering emphasises designing for the entire lifecycle of the home. This includes not just the immediate retrofit but how the home will perform over time in terms of energy use, maintenance, and environmental impact.
- **Feedback loops:** A systems thinking approach identifies feedback loops, such as how improving energy efficiency might reduce energy bills, which can then be reinvested into further upgrades. These positive feedback loops help sustain ongoing improvements.
- **Stakeholder collaboration:** Systems engineering involves engaging all stakeholders, homeowners, retrofit contractors, architects, engineers, energy auditors, etc., in doing so it allows requirements capture to be more comprehensive and representative of the needs of all those involved.
- **Risk management:** By understanding the system and the interfaces between each component, risks can be mitigated through careful planning, contingencies, and performance insurance

What does interoperability mean for Transform-ER and retrofit?

As outlined by the Connected Places Catapult (Connected Places Catapult, 2020); moving towards standard interfaces, developing kits-of-parts, and mass customisation are key value propositions as part of the roadmap to achieving retrofit at scale.

In the context of systems engineering or systems thinking for the built environment and retrofit, this means understanding the interactions between all elements within the whole-house retrofit system and how they contribute to its function. If the strategic goal for whole-house retrofit is to reduce emissions, increase energy efficiency, and improve occupant comfort; the interacting retrofit products and therefore the adaptable kits-of-parts must be compatible in delivering the performance of the overall system i.e. the dwelling. This is critical for unlocking finance and insurance, based on guaranteed outcomes.

Transform-ER aims to develop retrofit products through a standardised, repeatable and manufacturer agnostic approach, utilising common [rules](#) and standard details to enable Energy Efficiency Measures (EEM)/product [interoperability](#) for the whole-house retrofit. This approach de-risks and streamlines the retrofit process, making it repeatable at scale.

The scope of the Transform-ER Retrofit Rulebook is to define how manufacturers can work together in developing their products, using common rules and developing standard details for interfaces. Interoperability also goes beyond the physical product and considers aspects such as data interoperability – these aspects will also be explored in the Retrofit Rulebook.

How can Manufacturing-Led solutions facilitate retrofitting the UK's housing stock?

Industrialised or Manufacturing-Led solutions can significantly help address the UK's retrofitting challenges by offering scalable, efficient, and cost-effective approaches. The benefits from Manufacturing-Led approaches are:

- **Increased productivity and speed:** Prefabricated or modular components and kits-of-parts can be mass-produced in controlled environments, ensuring high quality and reducing installation time onsite.



“With conventional methods, the renovation of a district of this size would have taken around 10 years. Serially, we can do it in one and a half to two years.”

Guido Sinn, Technical Director of Beamten-Wohnungs-Baugenossenschaft eG (Energiesprung DE, 2024)

- **Cost reduction:** By standardising parts and streamlining processes, industrialised methods and economies of scale can lower costs of materials and labour.
- **Quality control:** Manufacturing in a controlled environment ensures that materials and components meet quality standards. Offsite manufacturing reduces the risk of poor onsite construction or substandard materials by ensuring defects are found before going on site.

- **Quality assurance:** Adopting a manufacturing approach ensures processes and procedures are in place to ensure quality standards are maintained at every step, through documentation, monitoring, and auditing; as well as ensuring competent skilled workers are fully trained for specific tasks.



“With serial refurbishment, we are three to four times faster than with conventional energy-efficient modernisation. Another advantage is the consistently high quality, which cannot be achieved even with the best craftsmanship. Since nothing is glued and all layers can be neatly separated from each other, the facades can also be recycled without any problems.”

Frank Melzer, Deputy Branch Manager of the B&O Group

- **Meeting standards:** The combination of Quality Assurance and Quality Control – as part of a Quality Management System – ensures a consistent standard of retrofit product is delivered every time, particularly where testing and certification has been undertaken to validate performance, such as fire.
- **Minimising disruption:** Offsite manufacturing minimises the time needed for onsite work, reducing the disruption to occupants and communities. Additionally, by minimising the proportion of work carried out onsite, project disruptors such as weather are also mitigated.

- **Innovation, sustainability:** Industrialised methods can incorporate technologies such as factory-built energy-efficient panels, insulation systems, or integrated components; facilitating the implementation of sustainable solutions.



“Years ago, one might have considered simply demolishing the Chiron estate. We don’t do that. The building fabric is there. We prefer to make the buildings fit for a climate-neutral future.”

Horst Riess, Managing Director of Wohnbau Tuttlingen GmbH (Energisprung DE, 2024)

- **Addressing skilled labour shortages:** Industrialised approaches reduce the reliance on skilled labour onsite and reduces the risks associated with onsite works, increasing good health and safety practice.
- **Stable and repeatable offsite process:** Once achieved, the application of appropriate technologies such as a digital quality management system or automation will enable repeatable, standardised processes.
- **Traceability of materials:** Ensuring an accurate record of the materials used from raw material source and throughout the lifecycle, from production through to construction, ensures a golden thread of information can be recorded digitally.

- **Production efficiency:** As well as increasing productivity of onsite processes, once manufacturing capability and capacity has ramped up, organisations can reduce waste and drive productivity further through interventions such as Lean Manufacturing and Continuous Improvement, as detailed further in this [Capability for Modern Construction Case Study](#) (The MTC, 2022).

- **Predictability of supply and demand:** Once a stable and repeatable offsite process has been achieved, aggregation of demand can be fed into an organisation’s pipeline. Production output can be planned to meet this demand through use of manufacturing techniques such as [Enterprise Resource Planning](#) (ERP), enabling accurate forecasting of production output, resource and cost.

- **Enabling new funding mechanisms:** Standardisation of kits-of-parts and the overall retrofit delivery model enables greater access to financial products. Repeatable and de-risked packaged retrofit projects makes them scalable and therefore attractive for investors, as described previously in this report ([Unlocking Finance](#)).

Applying Manufacturing-Led solutions to existing assets

Applying Manufacturing-Led solutions to existing assets comes with additional challenges that are not present for new-build construction. These include variability of asset features, lack of accuracy and quality of existing data, understanding of the performance of the asset, alignment or fixing of numerous old and new interfaces, and range of tolerances between the new products and the existing elements.

These challenges can be addressed by:

- **Defining objective methods** to determine the condition and geometry of the existing buildings, to assess the current performance, verify the retrofit installation integrity, and validate retrofit performance.
- Facilitating tools to achieve **better forecasting** of the **pipeline** for projects and streamlining processes.
- Leveraging **digital technologies** to streamline and automate the process of designing or selecting the optimal retrofitting solution.
- Facilitating Manufacturing-Led supply chains to enable delivery at scale and pace.
- Creating standardised retrofit methods, for deployment at scale and pace, while considering future adaptability. Physical and digital [interoperability](#) are key to ensure the success of the solutions.
- Developing the required quality protocols.
- Developing automated metrology, non-destructive testing and monitoring techniques.

Industrialised solutions must add value and result in the delivery of attractive products to boost acceptance in industry and society. The Connected Places Catapult, in their Retrofit Towards a Sector-wide Roadmap 2020 (Connected Places Catapult, 2020), outlines the case for two key value propositions relating to a Manufacturing-Led approach for retrofit:

- **Replicable, integrated interventions - the 'Retrofit Kit':** a menu of components, based on standard interfaces and connections, that are reliable, predictable and flexible and could be used to construct a solution for any property.
- **Mass customisation:** modern methods of construction that combine mass factory production with adaptation of standard kits, 'pop-up' factories and local supply chains.

If the UK is to deliver retrofit at scale, fundamental to this is the UK supply chain's capability to produce interoperable products and systems, enabling retrofit projects across the country to deploy off-site manufactured kits-of-parts, delivered on time, in budget and to quality requirements, such as UK building regulations and retrofit performance standards.

Therefore, standard design details, standardised interfaces and rules governing a standardised approach to retrofit need to be developed to unlock 'mass customisation' and 'the retrofit kit' defined by the Connected Places Catapult.

This outlines the need for a best practice guide in the form of the Transform-ER Retrofit Rulebook.

Case Studies



Examples of a manufacturing approach to construction can be taken from the Transforming Construction Challenge for new build government pipeline, including:

The Seismic Platform

- **75%** improvement in speed and efficiency
- **70%** reduction in carbon
- **47%** improvement in value across the project programme.

The manufacturing benefits for the Seismic Platform are outlined further in the [Capability for Modern Construction Case Study](#) (The MTC, 2022).



Figure 6: Seismic Platform, BRE Watford.

The AIMCH project

[The Advanced Industrialised Methods for the Construction of Homes \(AIMCH\)](#) project included Modern Methods of Construction at scale on real housing sites, versus traditional methods. Partners estimated a productivity increase ranging from 30% to 50% for different processes, as well as gaining the benefits of cost reduction, quality assurance, increased health and safety, and 50% reduction in build time (AIMCH, 2022).

Energiesprong Germany

External to the TCC, but showcasing how a Manufacturing-Led approach to retrofit can be adopted to increase pace and scale of deployment, examples of achieving whole house retrofit using offsite constructed products can be found via Energiesprong Germany, including:

- 40 apartment buildings and a total of 338 residential units in [Düsseldorf](#) upgraded to the highest German energy rating, including prefabricated wooden façade elements (Energiesprong, 2024).
- Partners estimated a productivity increase ranging from 30% to 50% for different processes, as well as gaining the benefits of cost reduction, quality assurance, increased health and safety, and 50% reduction in build time.

Define the need methodology

The Transform-ER Define the Need methodology has been directly informed by the Construction Innovation Hub's [Define the Need report](#) (CIH, 2021), albeit for retrofit of existing UK housing stock as opposed to new build construction for Government departments.

In seeking to develop [interoperable kits-of-parts](#), the Transform-ER consortium has sought to analyse the market opportunity for industrialised retrofit. We have been informed primarily by UK housing stock data and by the Transform-ER consortium. The methodology has been structured around five main steps:

1. Gather sources of data
2. Data analysis
3. Quantify the retrofit demand
4. Harmonise requirements
5. Conclusions, recommendations and next steps.

Step 1 - Gather sources of data

To define the scale of UK dwellings to be retrofitted in the short, medium, and long term and the extent to which a platform/Manufacturing-Led approach could be applied, several sources were used to analyse the pipeline demand for new retrofit projects to meet net zero 2050 targets.

These included:

- Northern Ireland House Condition Survey, NIHCS - (NIHCS, 2016)
- Welsh Housing Conditions Survey, WHCS - (WHCS, 2017)
- The Housing Stock of the United Kingdom - (BRE Trust, 2020)
- Climate Emergency Retrofit Guide (LETI, 2021)
- Scottish House Condition Survey, SCHS - (SHCS, 2022)

- The English Housing Survey, EHS - (EHS, 2023)
- Statistics from Ministry of Housing, Communities & Local Government, MHCLG* - (MHCLG, 2024)
- Household Energy Efficiency Statistics, headline release September 2024 (DESNZ, 2024).

* Was Department for Levelling Up, Housing and Communities (DLUHC).



Neighbourhood of homes retrofitted in Nottingham, UK with a fabric-first approach. Credit - Energiesprong UK

How can the data be used?

The effective use of the housing stock data, in combination with considering strategic value-based outcomes, as considered in the likes of the [Value Toolkit](#) or the [Green Book](#), can help determine strategic objectives by identifying the desired outcomes, quantifying the specific demand, and developing a pipeline of work. This is important to consider when identifying the target market or segment of the existing housing stock to address by retrofit stakeholders.

A general overview of the UK housing stock is shown in Table 1:

Table 1: Breakdown of the UK housing stock across the whole of the UK by dwelling type, age, tenure, and location in '1000s of homes (EHS, 2024 (WHCS, 2017) (NICHs, 2016).

	ENGLAND	SCOTLAND	WALES	NORTHERN IRELAND	UK
Dwelling age					
pre-1919	5,099	466	351	82	5,998
1919-44	3,801	284	133	68	4,286
1945-64	4,550	523	219	126	5,418
1965-80	4,674	570	304	189	5,737
1981-90	1,660	224	99	99	2,082
post 1990	5,376	483	235	216	6,310
Dwelling type					
All Terrace	7,319	543	376	221	8,459
Semi-detached	6,169	496	369	180	7,214
Detached	4,388	578	296	164	5,426
Bungalow	1,997	-	154	164	2,315
Flat	5,228	933	147	52	6,360
Dwelling tenure					
Owner occupied	15,685	1,649	924	512	18,770
Private rented	4,363	293	180	146	4,982
Social rented	3,974	609	238	122	4,943
Location					
Urban	21,070	2,127	900	503	24,600
Rural	4,091	422	441	277	5,231
<i>Total dwelling stock</i>	25,160	2,550	1,342	780	29,832
<i>Average dwelling size (m2)</i>	97	97	102	105	97.4
Dwelling age					
pre-1919	20.3%	18.3%	26.2%	10.5%	20.1%
1919-44	15.1%	11.1%	9.9%	8.7%	14.4%
1945-64	18.1%	20.5%	16.3%	16.2%	18.2%
1965-80	18.6%	22.4%	22.7%	24.3%	19.2%
1981-90	6.6%	8.8%	7.4%	12.8%	7.0%
post 1990	21.4%	18.9%	17.5%	27.7%	21.2%
Dwelling type					
all terrace	29.1%	21.3%	28.0%	28.3%	28.4%
semi-detached	24.5%	19.5%	27.5%	23.0%	24.2%
detached	17.4%	22.7%	22.1%	21.0%	18.2%
bungalow	7.9%	-	11.5%	21.0%	7.8%
Flat	20.8%	36.6%	11.0%	6.7%	21.3%
Dwelling tenure					
Owner occupied	62.3%	64.7%	68.9%	65.6%	62.9%
Private rented	17.3%	11.5%	13.4%	18.7%	16.7%
Social rented	15.8%	23.9%	17.7%	15.6%	16.6%
Location					
Urban	83.7%	83.4%	67.1%	64.0%	82.5%
Rural	16.3%	16.5%	32.9%	36.0%	17.5%
Source Year	2022	2022	2017	2016	

The data sources stated can be used to develop a fuller understanding of the UK dwelling stock based on the key characteristics discussed. No single source exists that can fully define the scale of dwellings that need to be retrofitted (over the next three decades), and the extent to which a manufacturing approach could be applied. Therefore, assessment of the identified sources is integral to understanding any limitations and gaps to allow an accurate calculation of pipeline demand for new retrofit projects to meet NZ2050 targets.

It is important to use accredited official statistics when analysing the UK housing stock (Office for Statistics Regulation, 2024).

Housing Surveys

Housing condition surveys are fundamental for dwelling stock categorisation. Within the UK there are four different housing surveys undertaken, one for each of the devolved nations.

Each of the UK nations conduct housing surveys aiming to collect information relating to housing stock conditions and circumstances. Both physical inspections and household interviews are conducted and used to form a comprehensive picture of the housing stock by utilising both quantitative and qualitative data.

Each country has varying sample sizes for data collection. This includes a stratified random sampling methodology that reduces bias by considering factors like geographical location, housing tenure and property type. The limited sample sizes of participants can lead to under-representation of sub-groups or regions across the UK and lacks the granularity of localised data.

There is no set standard for the housing attributes that each country must include in their reports. Despite this, most explore a set of common and universal characteristics. Definitions and contents of identical categories can vary i.e. Scotland doesn't record Bungalows for Dwelling Type. Hence, there are discrepancies in data reported between the individual countries' datasets. This does, however, enable countries the freedom to focus data collection on specific issues particular to their housing stock.

The primary focus of the surveys is to provide estimates on the condition of dwellings, whereas in addition the EHS investigates housing circumstances. Table 2 shows that there is no set timeframe for which a survey must be conducted, leading to large periods without reported data. There is a significant lag in data between the time of recording and time of publication. Ultimately this results in outdated statistics, especially from Wales and Northern Ireland, which leads to inaccurate live representation of the UK landscape that does not capture rapid changes in trends.

Covid-19 is partially to blame for this, increasing the difficulty to collate data and publish it; along with the cost of living crisis, both of which have dramatically influenced UK housing trends in ways which have not been accounted for.



Table 2: Data illustrating the frequency with which surveys were conducted in each of the UK nations (P = physical, I = interview).

	ENGLAND		SCOTLAND		WALES		NORTHERN IRELAND	
	P	I	P	I	P	I	P	I
2004	✓	✓			✓	✓	✓	✓
2005	✓	✓				✓		
2006	✓	✓	✓	✓		✓	✓	✓
2007	✓	✓	✓	✓		✓		
2008	✓	✓	✓	✓	✓	✓		
2009	✓	✓	✓	✓			✓	✓
2010	✓	✓	✓	✓				
2011	✓	✓	✓	✓			✓	✓
2012	✓	✓	✓	✓		✓		
2013	✓	✓	✓	✓		✓		
2014	✓	✓	✓	✓		✓		
2015	✓	✓	✓	✓		✓		
2016	✓	✓	✓	✓		✓	✓	✓
2017	✓	✓	✓	✓	✓	✓		
2018	✓	✓	✓	✓		✓		
2019	✓	✓	✓	✓		✓		
2020	✓	✓		✓		✓		
2021	✓	✓	✓	✓		✓		
2022	✓	✓	✓	✓		✓		

Recent trends that are not necessarily reflected in the surveys include:

- More of the UK population working from home
- Covid-19 impact on housebuilding progress
- Rising cost of energy
- Cost of living crisis impacting personal savings and therefore ability to invest in retrofit measures
- Stagnation in reducing fuel poverty - remained above 3.16 million homes from 2020 to 2023 (DESNZ, 2024)
- 1 in 11 social homes are in fuel poverty (Switcher, 2024).

Covid-19 had a significant impact on the methodology of housing surveys across the UK between 2020-22, more specifically England and Scotland due to social distancing restrictions. Face-to-face interviews were replaced with telephone interviews, and internal property inspections were substituted with external inspections, supplemented by internal data collected through socially distanced doorstep assessments.

The timeline for the publication of the next iteration of the WHCS remains uncertain. Limited housing data is made available annually through the National Survey for Wales. In April 2024 Cabinet Secretary for Housing, Local Government and Planning Julie James MS said, “an annual conditions survey would be too expensive” (Welsh Parliament, 2024).

The NIHCS aims to conduct surveys approximately every five years. The 2021 edition was postponed due to the Covid-19 pandemic. The most recent survey, conducted in 2023, is currently undergoing quality assurance and is expected to be published shortly.

Data limitations

The main data sources used to calculate and analyse the pipeline demand for new retrofit projects carry countless data limitations that affect the validity or usability of the data for research. The following concerns have been identified in Table 3.

Table 3: Summary of the limitation associated with the use of housing survey data.

Category	Description	Example	Limitation
Data completeness	Missing or incomplete data in a dataset	WHCS has incomplete data due to low physical inspection numbers	Reduces the accuracy of conclusions and insights
Data accuracy	Data contains errors or inaccuracies	~30% of buildings on the Energy Performance of Building Register have been misclassified	Leads to misleading results or incorrect conclusions
Data timeliness	Data is outdated and no longer reflects the current trend	NIHCS was last published in 2016	Leads to outdated and irrelevant insights and conclusions
Sample size	The number of data points in a dataset	Only ~12,400 physical inspections in each edition of EHS, ~0.05% of the total dwelling stock	Data may not fully represent dwelling diversity, skewing results towards outliers
Data granularity	Data is either too detailed or too aggregated for analysis	Housing surveys don't include regional or local data	Limits the ability to create a localised retrofit strategy and identify priority regions
Data latency	Delays in data availability after collection	NIHCS 2023 has been conducted, yet is still unpublished	Leads to outdated and irrelevant insights and conclusions

Category	Description	Example	Limitation
Data availability	Difficulty accessing the required data	SHCS does not publicly publish all data that is recorded	Limit the scope and coverage of which conclusions can be drawn
Measurement errors	Errors in data collection	Different DEA assessors often score dwellings differently due to personal interpretations of SAP	Leads to inaccurate results
Data consistency	Inconsistent formats or structures of data	There is no standard for housing attributes each country must include in reports	Difficulty in merging data and comparing countries
Data integration	Challenges in merging data across multiple sources	Differences in the intervals used to record dwelling age or loft insulation levels	Leads to inconsistent formats and semantic mismatches

Step 2 - Data analysis

Some of the key statistics to highlight from the data referenced in Step 1 include:

1. Most common dwelling in the UK

According to the housing surveys, terraced housing is the most common at 8.5 million, semi-detached is the second most common at 7.2 million homes.

2. Energy Performance Certificate - EPC

Given the commitments made by the new [Labour government on EPC ratings](#), based on housing survey data from all UK nations, it can be estimated that roughly 50% of the UK housing stock is still rated at band D and lower.

3. Fuel type in the UK

23 million (85%) homes are gas fuelled.

4. Social housing in the UK

4.9 million homes are socially rented.

Figure 7 and Figure 8 visualise the interaction of UK housing stock by age, type, fuel and then by insulation type, using the sources stated in Step 1.

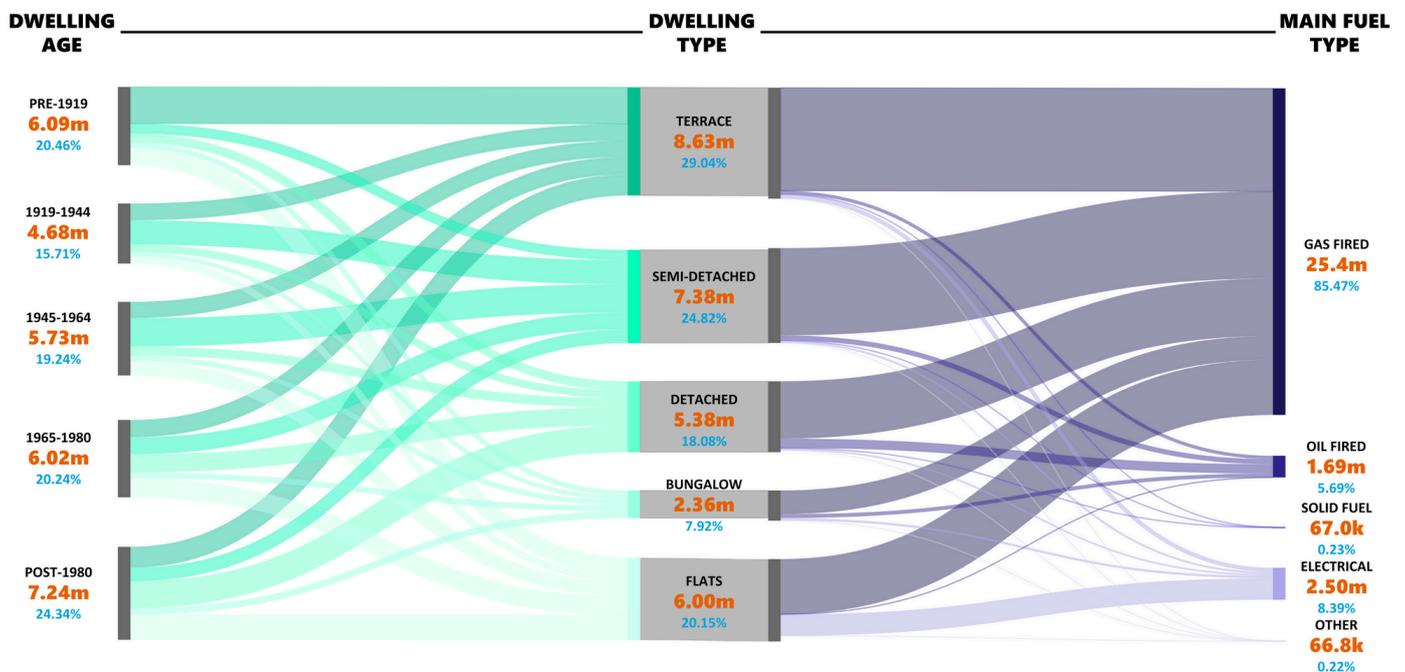
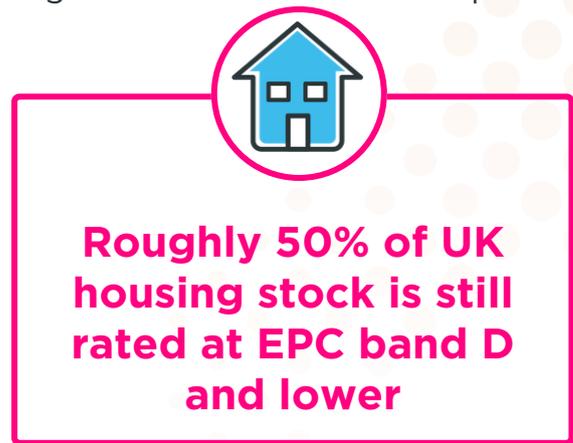


Figure 7: Diagram illustrating the distribution of housing across age, dwelling type and fuel type.

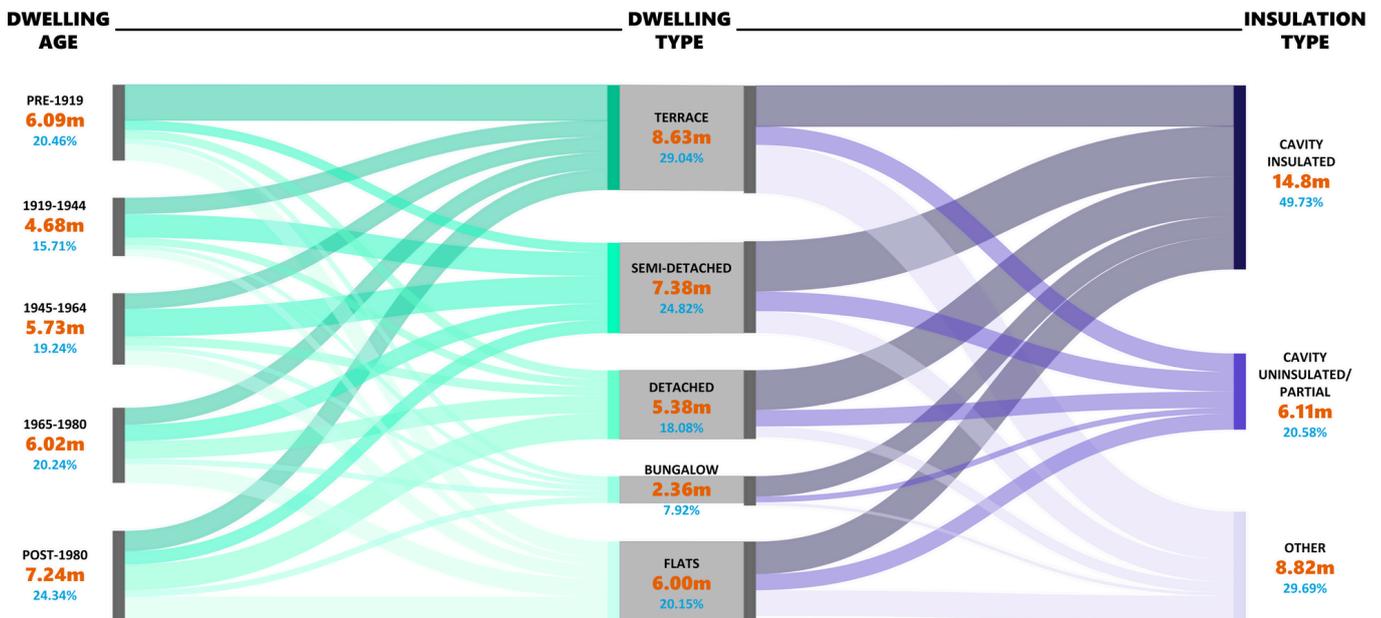


Figure 8: Diagram illustrating the distribution of housing across age, dwelling type and insulation type.

Dwelling age

Period in which the oldest section of a dwelling was originally constructed.

Different building eras reflect distinct and recognisable construction practices influenced by historical building techniques, national economic conditions, and housing demand.

There is a negative correlation between dwelling age and property condition, which can significantly impact retrofit costs. This is largely due to the extensive maintenance and repairs that older properties demand due to deterioration.

Older properties tend to be less energy efficient due to the use of outdated materials and technologies in their construction, making them prime candidates for retrofitting compared to modern dwellings which are more energy efficiency focussed.

These opportunities include simple measures such as insulation and double glazing. However, there are often restrictions due to conservation regulations that can prevent or complicate the installation of certain measures.

Figure 9 gives a breakdown of the UK dwelling age by each country.

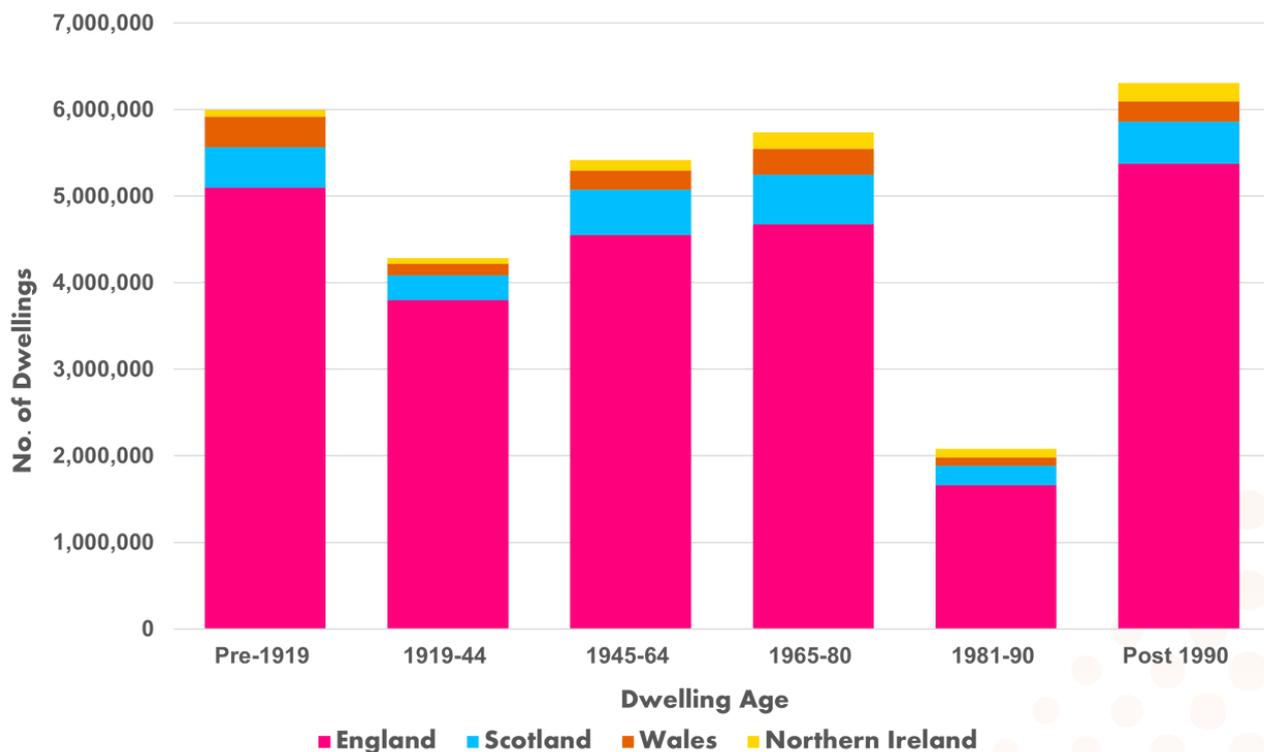


Figure 9: Dwelling age breakdown of UK housing stock (EHS, 2023), (SHCS, 2022), (WHCS, 2017), (NIHCS, 2016).

Construction type

Classification of buildings based on the materials used and the methods employed during construction.

Non-traditional buildings - also known as 'Non-standard' - make up a small but significant portion of the UK housing stock. These pose a unique set of challenges, whether that be the lower thermal mass, increased likelihood of proneness to degradation, or reduced load bearing capacity.

BRE have estimated that there are over 500 different types of non-trad housing that were constructed between 1919 and 1976 (BRE, 2012) of which a total of 1.5 million were thought to have been constructed through the 1940s to 1970s (Allcock, n.d.).

Non-traditional housing can be categorised into the following four groups:

- Timber frame
- Metal frame
- In situ concrete
- Precast concrete.

Traditional or standard homes in the UK typically refer to houses built using conventional construction methods and materials that have been prevalent over recent centuries. 'Standard houses' consist of brick or stone walls with a roof made of slate or tile.

Solid wall popularity was overtaken by cavity wall build from the late 1930s (University of the West of England, 2009), resulting in cavity wall being the most common type of dwelling in the UK building stock.

EPC rating

An Energy Performance Certificate (EPC) indicates the energy efficiency of a building. The assessments are banded from A to G, where A (or A+ for non-domestic properties) is the most efficient in terms of likely fuel costs and carbon dioxide emissions.

The EPC includes recommendations to occupiers to make cost effective improvements to the energy efficiency of a building. (Ministry for Housing, Communities & Local Government, 2021). A separate Environmental Rating scores the property on its CO₂ emissions.

Energy Performance Certificates (EPC) are one of the primary metrics used by government and other organisations for evaluating and improving the energy efficiency of the UK's housing stock by assessing a building's fabric and services (Ministry of Housing Communities & Local Government, 2017).

They were introduced in 2002, and later recast in 2010, in response to the EU Energy Performance in Building Directive (EPBD).

To generate a rating, information such as a building's thermal insulation, heating system and ventilation is gathered and fed into the Standard Assessment Procedure (SAP) algorithm.

They are a legal requirement for all dwellings that are constructed, sold, or let and are valid for 10 years.

According to the most recent housing survey data just over 47% of homes in the UK meet the recommended EPC rating of 'C' or above (EHS, 2024), (SHCS, 2022), (WHCS, 2017), (NIHCS, 2016), see Figure 10 below.

Lower EPC ratings may indicate significant potential for retrofit interventions and can allow access to grant funding or 'green' financial products due to these properties often suffering from poor thermal comfort, air quality and higher operating costs.

Average (median) fuel costs of A-C rated households are around three times less than those rated G (ONS, 2022), resulting in 'A' rated homes in the Welsh housing market commanding a 12% price premium compared to 'D' rated homes, while 'F' rated properties may experience a 6% value reduction (Fuerst, et al., 2016).

Regional analysis of EPC data can identify areas with high retrofit potential, therefore enabling targeted resource allocation to maximise impact. Improving the energy efficiency of existing dwellings typically involves upgrading heating systems and enhancing insulation. It is important to acknowledge that the energy efficiency rating reflects energy costs per unit area rather than true efficiency of a building. Inbuilt assumptions around cost and efficiency mean that adding low carbon heating measures such as heat pumps can result in a worse EPC rating than higher carbon gas boilers.

The two main sources, housing surveys (EHS, 2024) (WHCS, 2017) (SHCS, 2022) (NIHCS, 2016) and the Energy Performance of Buildings Register (Ministry for Housing, Communities & Local Government, 2021) (over 26 million logged EPC ratings), provide conflicting reports of the actual state of energy efficiency in the UK.

The ratings on the register are calculated by official surveyors using the SAP methodology, unlike those from housing surveys that use internal and external physical inspections from EHS surveyors to estimate a SAP rating.

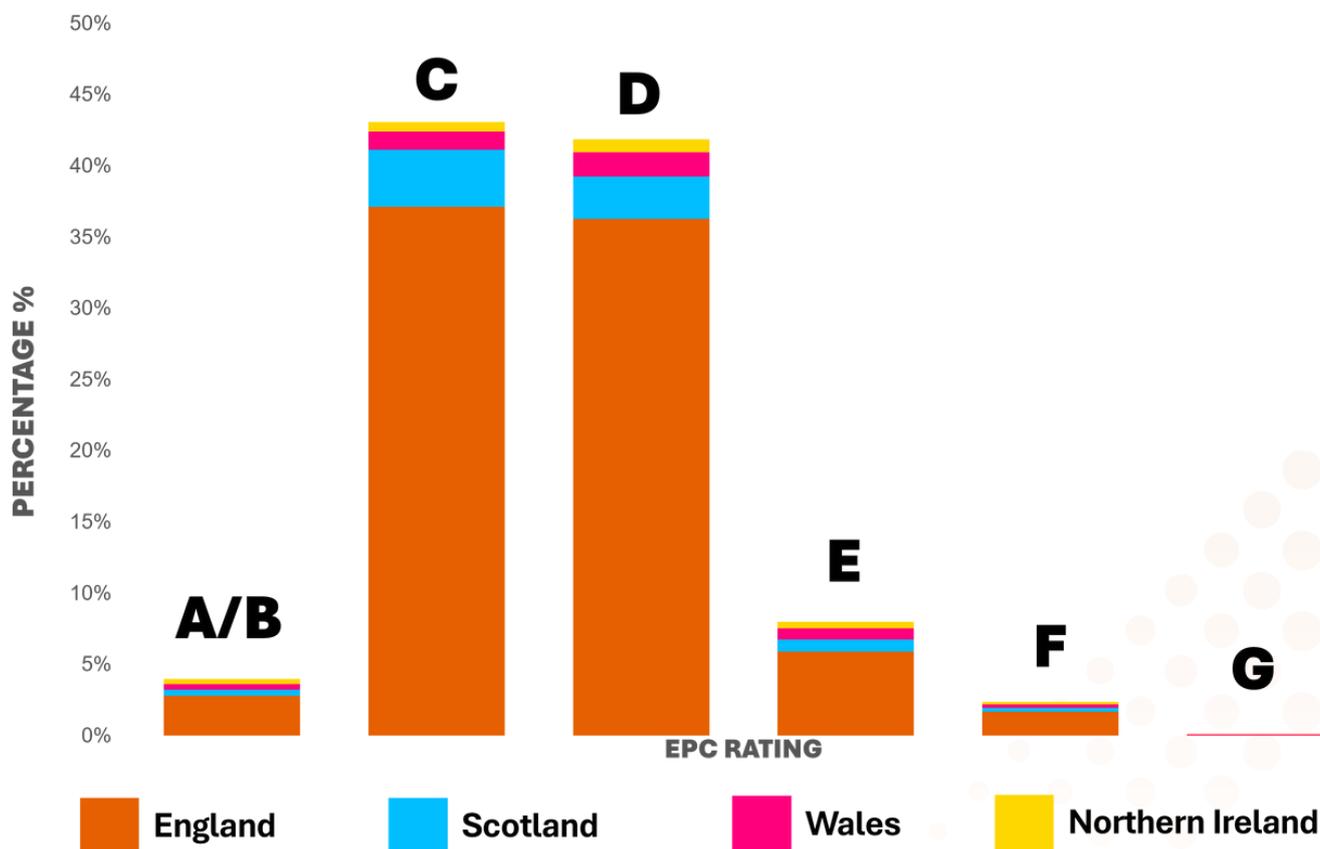


Figure 10: Distribution of EPC rating by nation (EHS, 2024), (SHCS, 2022), (WHCS, 2017), (NIHCS, 2016).

Regardless of the limited sample size and differing methodology, the unofficial housing survey values may provide a truer representation of the landscape of the stock as assessors are less likely to manipulate EPC inputs in favour of ensuring a more positive result. These assessors are under less influence of landlords and homeowners, for example, to meet minimum letting rating requirements and greater property values, or to get lower rates required by grant fundings.

Output from EPC assessments of the same property can significantly differ (Jenkins, et al., 2017). From the Green Deal Assessment Mystery Shopping Research, where multiple Domestic Energy Assessors (DEA) assessed the same properties.

The average range in Energy Efficiency Ratings (EER) was 11 points and one property reported more than 30 points, largely due to differences in assessor interpretation (Department of Energy & Climate Change, 2014).

The true percentage error in EPC ratings has been estimated to range from 32% to 62% on the register, with an average deviation of approximately four points in the energy rating. Based on the analysed sample, this discrepancy would result in approximately 30% of properties being misclassified into incorrect EPC bands (Hardy & Glew, 2019). Inaccuracies are higher in certain regions due to tenure type, primarily linked to dwelling concentrations of flats/maisonettes and the associated challenges in location assessment within the building and in evaluating the surrounding space (Hardy & Glew, 2019).

Other inconsistencies also exist since the version of the SAP methodology used to produce EPCs has not been updated for almost a decade. Methodological differences between the current version (SAP2012) and the latest version (SAP 10) mean that EPC ratings can vary significantly with the same inputs. Government has recognised these concerns and is developing a new methodology called the Home Energy Model. However, in the meantime, SAP2012 continues to be used.

EPC ratings are valid for 10 years, in which time the state of energy efficiency of a building may have drastically changed, either improving by applying retrofit measures or worsening through degradation of the dwelling condition. There is a government plan to rectify the shortcomings and reform EPCs into a more reliable, consumer-friendly tool to align with home improvements and UK NZ2050 ambitions.

Dwelling type

Refers to the classification of living spaces based on their structure, design and intended residential use.

The UK has a well distributed range of different dwelling types. Unlike many other European countries, over 52% of its housing stock consists of “conjoined” dwellings, such as terraced or semi-detached houses (BRE Trust, 2020), highlighting the importance of developing an interoperable ‘kit-of-parts’ or interfaces between properties. Hence, the most common type of occupied dwellings across England and Wales is semi-detached houses at 31.5% (Office for National Statistics, 2023).

The UK dwelling stock can be broken down into five generalised classifications, summarised in Figure 11.

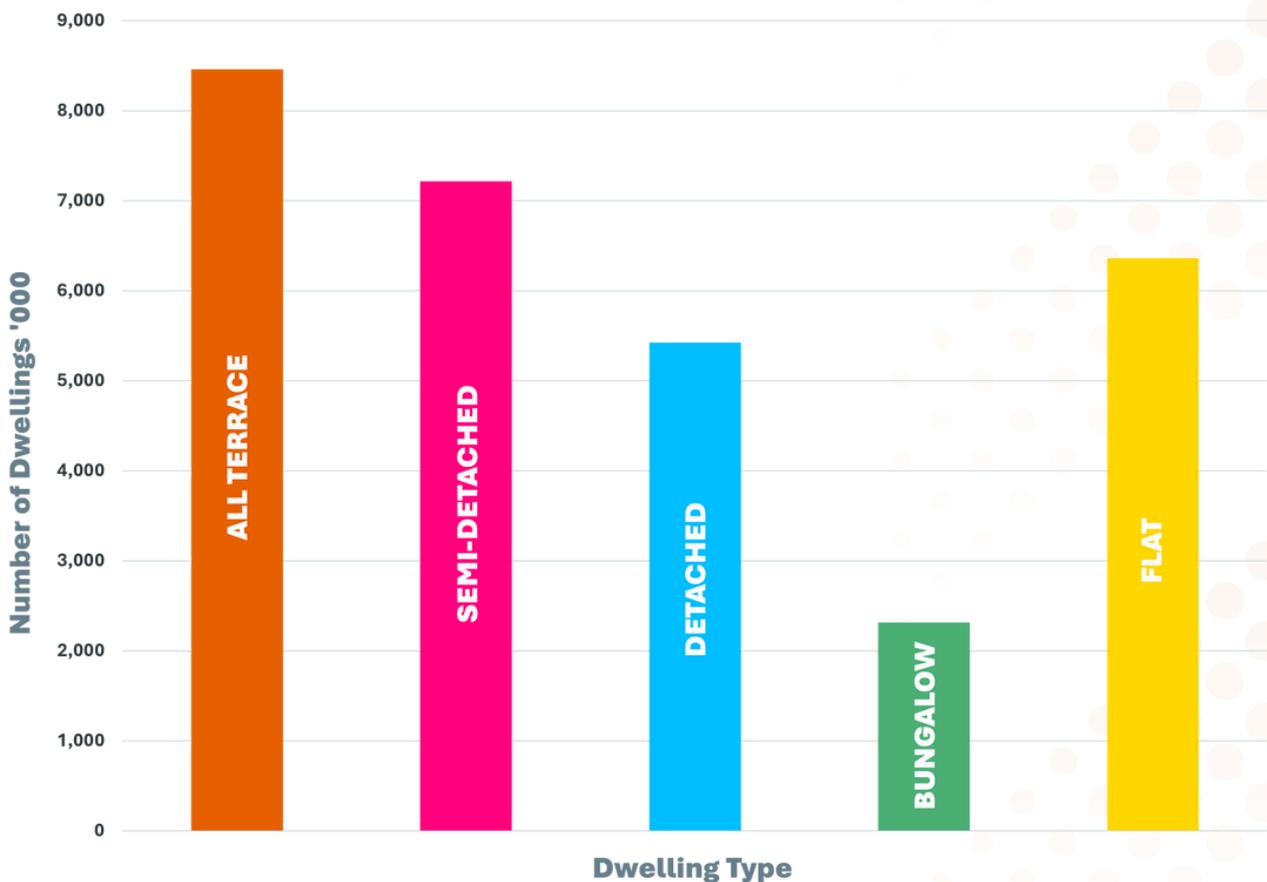


Figure 11: Chart illustrating the distribution of different dwelling types across the UK (EHS, 2024), (SHCS, 2022), (WHCS, 2017), (NIHCS, 2016).

Each dwelling type experiences a unique set of challenges due to the distinct physical characteristics associated with their form, ultimately impacting the viability of retrofit measures.

Understanding these features is essential to ensure the success of a retrofit and to enable designers to tailor their work to address the specific demands of each type. This variation can substantially influence the cost associated with a retrofit project. A targeted approach may prioritise certain dwelling types based on their retrofit ease and greater opportunity for standardisation.

Condition

Dwelling condition incorporates housing quality measures from the decent home standard, Housing Health and Safety Rating System (HHSRS) and damp.

The HHSRS is a risk-based assessment that identifies hazards in dwellings and evaluates their potential effects on the health and safety of occupants and their visitors, particularly vulnerable people. Retrofit can have an even greater impact than just reducing energy consumption and carbon emissions with the ability to correct adverse health risks in the form of indoor air quality, mould and temperature, which can contribute to respiratory diseases and other health conditions.

Identifying properties in a reasonable state of repair is integral when assessing the potential implications that may occur when applying retrofit measures, as decay could indicate ballooning costs or limitations/failure to applicable measures. Such conditions could significantly undermine the effectiveness of insulation retrofits by trapping moisture, degrading insulation performance, and accelerating structural damage.

Currently, around one million homes in England have reported problems with damp (Ministry of Housing, Communities & Local Government, 2024). Having proper assessment of the property's condition is a crucial step prior to retrofitting.

Heritage and conservation

Listed buildings are buildings with special architectural or historic interest, which gives them legal protection. A conservation area is an area of special architectural or historic interest, the character, appearance or setting of which is desirable to preserve or enhance.

Approximately 25% of the UK housing stock, or around 7 million homes, are subject to heritage or architectural constraints (LETI, 2021). Approximately 40% of those 7 million homes face heritage protection from the 10,000+ unique conservation areas across the UK (Architects Climate Action Network, 2023). In addition, properties can qualify based on construction age, character, or historical significance, of which 370,000 listed buildings exist within England alone (Historic England, 2024).

These buildings face constraints on the types and extent of retrofits that are applicable. Constrained dwellings tend to contribute a greater proportion of carbon emissions than typical homes, contributing to 5% of the total UK CO₂ emissions (Architects Climate Action Network, 2023).

Retrofitting such buildings externally poses challenges such as the difficulties and costs associated with their historical and architectural features, which could impact their market and social value. Internal retrofits may also be restricted by space constraints as internal thermal improvements often reduce usable floor area.

Consequently, achieving optimal energy efficiency in these buildings will likely require specialist consultation to ensure appropriate and tailored retrofit solutions are applied on a case-by-case basis.

Insulation

Insulation is an energy efficiency measure which aims to minimise thermal bridging to reduce heat losses and reduce the demand for and the required capacity of the heating system of a dwelling.

Insulation is one of the greatest energy efficiency measures applicable to a dwelling by complementing the building’s thermal mass. Poorly insulated homes lose significant heat in the winter and struggle to stay cool in the summer, leading to an increased reliance on heating and cooling systems, which drives up energy bills. Pre-1930 terraced houses are the archetype that suffer from the lowest ratings of wall and roof insulation (ONS, 2023).

Standard insulation measures include cavity or solid wall insulation, loft insulation, and double glazing. In 2022 just over half (52%) of dwellings had cavity or solid wall insulation compared to the 88% of homes that had full double glazing (Ministry of Housing, Communities and Local Government, 2023). Insulation creates a consistent indoor temperature which is beneficial for health and comfort.

Tenure

Defines the conditions under which the home is occupied, whether it is owned or rented, and if rented, who the landlord is and on what financial and legal terms the let is agreed. Figure 12 shows the tenure type by nation.

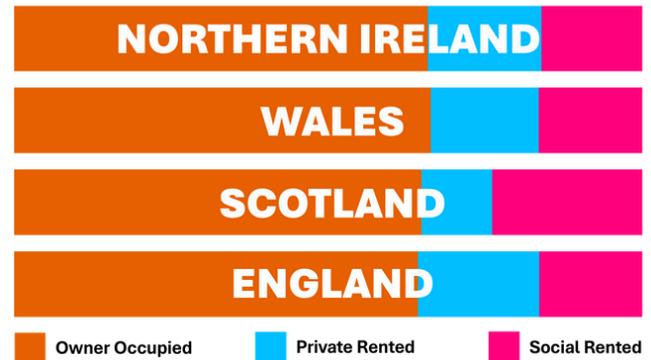


Figure 12: Dwelling tenure type by nation (EHS, 2024), (SHCS, 2022), (WHCS, 2017), (NIHCS, 2016).

The Private Rented Sector (PRS) suffers from the split incentive problem. Landlords bear the cost of a retrofit and energy efficiency measures, yet the occupier receives the benefits in the form of lower energy bills, leading to a reluctance from landlords to invest. In addition, the transient nature of tenants reduces the adoption of retrofitting in the private sector as short-term occupancy could deter landlords from investing in long-term energy efficiency measures.

In response, the government’s Minimum Energy Efficiency Standard (MEES) refers to the legal requirement that all let properties, including social housing, need a valid EPC rating of E or above unless exempt (Department for Energy Security and Net Zero, 2017).

A substantial number of socially rented properties have been enhanced with advanced heating systems, cavity-wall insulation, loft insulation, double glazing, energy-efficient lighting, and draught-proofing measures.

This trend can be largely attributed to the fact that most of these dwellings were constructed post 1945, in contrast to the predominantly older overall UK housing stock.

Despite social housing having greater access to specific government funding, the scale of funding required to deliver the required rate is likely beyond the feasible scope of public sector funding (Department for Energy Security & Net Zero, Department for Business, Energy & Industrial Strategy, 2019).

There remains substantial scope for improving the energy efficiency of social housing, with a particular emphasis on the necessity to insulate solid walls and install floor insulation, but these tend to be more complex and expensive.

The largest barrier to retrofitting owner-occupied and social housing alike is finance, whether that be the substantial upfront cost associated with a retrofit project or the lack of accessible capital through grants. The absence of governmental policies or incentives intensifies the problem of property owners' insufficient motivation to invest in their assets. This is despite the upside of reduced energy bills and increased property value that such measures would achieve after investment for homeowners.

Fuel poor homes

Fuel poverty is the condition by which a household is unable to afford to heat (or cool) their home to an adequate temperature.

Homes with the lowest EPC ratings are disproportionately represented across fuel poor homes. Upgrading the energy efficiency of homes is the most effective way of tackling fuel poverty. The methodology for calculating fuel poverty differs across the nations. In general, it relates to a property that must spend a high proportion of their income to keep their home at a reasonable temperature.

The percentage of Private Rented Sector (PRS) dwellings in England classed as fuel poor is around double that of households in social housing (Department for Energy Security & Net Zero, 2024).

The Government has a target that all fuel poor homes should be at least band C by 2030. Enabling this, households (mostly private) are eligible for support from the ECO scheme which will see current and future homes receive funding to improve the fabric of their homes to reduce fuel bills by achieving a C rating. ECO4 is estimated to upgrade around 450,000 homes, most of them to an EPC C, and generate an estimated £224.3 million in annual energy bill savings (BEIS, 2022).

Step 3 - Quantify the retrofit demand

There is currently no traceability of the overall number and depth of retrofitted homes in the UK (publicly or privately funded). To estimate the current retrofitting rate and the remaining retrofit potential, using the available data from DESNZ and the EHS, this section seeks to:

- Estimate retrofit delivery to date
- Discuss the UK retrofitting rate
- Use English Housing Survey data to estimate the remaining potential by measure and by dwelling type.

Retrofit market potential

A full economic analysis is required to build an accurate picture of the market value for retrofitting the UK's housing stock and contribution of this to the UK's GDP. High level calculations conducted by the MTC suggest the value of the market could range from £20bn to £60bn per annum.

Other sources suggest a retrofit market value of over £500 billion for domestic housing ([McWilliams, 2023](#)), and £250 billion of investment required before 2050 ([RICS, 2024](#)).

Retrofit Delivery to Date

Measures and government funding schemes

Data on measures undertaken since 2009 on a range of funding schemes are published by the government (DESNZ, 2024). Around 4.1 million energy efficiency measures have been installed in 2.7 million homes from 2013 to 2023 in Great Britain thanks to the support of different government schemes, Figure 13(a, b):⁵

- Energy Company Obligation (ECO)
- The Green Deal (GD) Framework
- Green Homes Grant Vouchers (GHGV)
- Local Authority Delivery (LAD)
- Home Upgrade Grant (HUG)
- Social Housing Decarbonisation Fund (SHDF)
- Great British Insulation Scheme (GBIS).



The value of the retrofit market could range from £20bn to £60bn per annum.

⁵ Other schemes have existed, such as Domestic Renewable Heat Incentive (RHI), and Feed in Tariff (FIT), however these were not included in the data used in this section provided by DESNZ.

The breakdown of targeted audience, measures installed by measure type, and funding scheme can be found in the statistical reports from DESNZ (DESNZ, 2024). Energy efficiency measures installed under government schemes include:

- Envelope upgrade measures: insulation measures, windows and doors
- Efficient energy generation/control measures: boiler measures, low carbon heat measures (heat pumps and solar thermal), solar PV, batteries, and heating controls.

The ECO scheme is the largest energy efficiency scheme delivering 94% of total installed measures (3.8 million), Figure 13(a). It focuses on private (rented and owner-occupied homes) delivering different type of measures throughout its different versions, Figure 13(b).

In 2023, 139,500 ‘other heating’ measures (53%) were installed – mainly heating controls – followed by loft insulation and micro-generation measures (heat pumps, biomass boilers and photovoltaics), with 14% and 10% measures installed, respectively.

For ECO measures installed up to 2023:

- 70% were installed in owner - occupied homes. The remaining share receiving measures were socially rented (16%) and privately rented (14%) homes
- 71% were houses (increasing up to 83% in 2023), followed by 18% of flats (noticeable drop from 2022 (30%) to 2023 (9%).

It was not until ECO4 that the scheme adopted a whole-house retrofit (WHR) approach whereby multiple measures are installed in a property following a full assessment, instead of a suite of shallow measures (in the best cases) or piecemeal shallow measures.

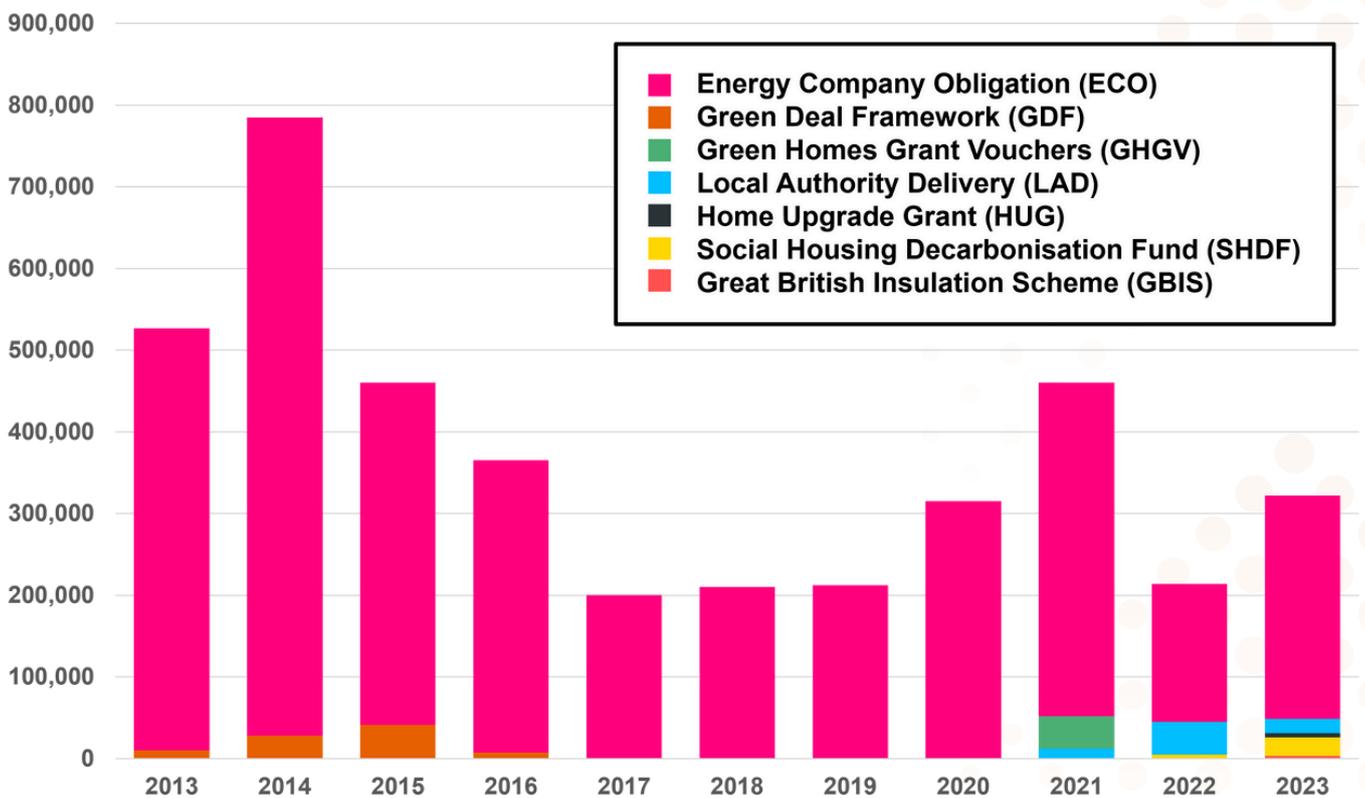


Figure 13 (a)

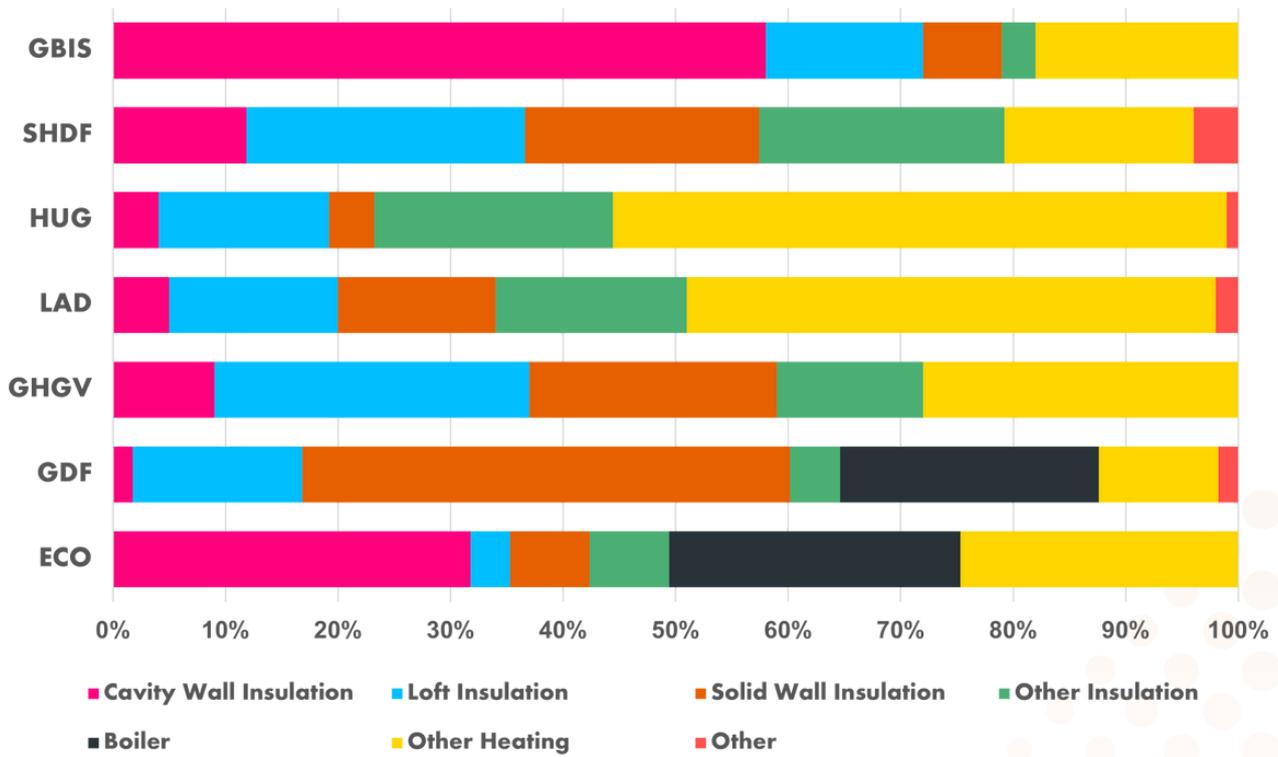


Figure 13 (b)

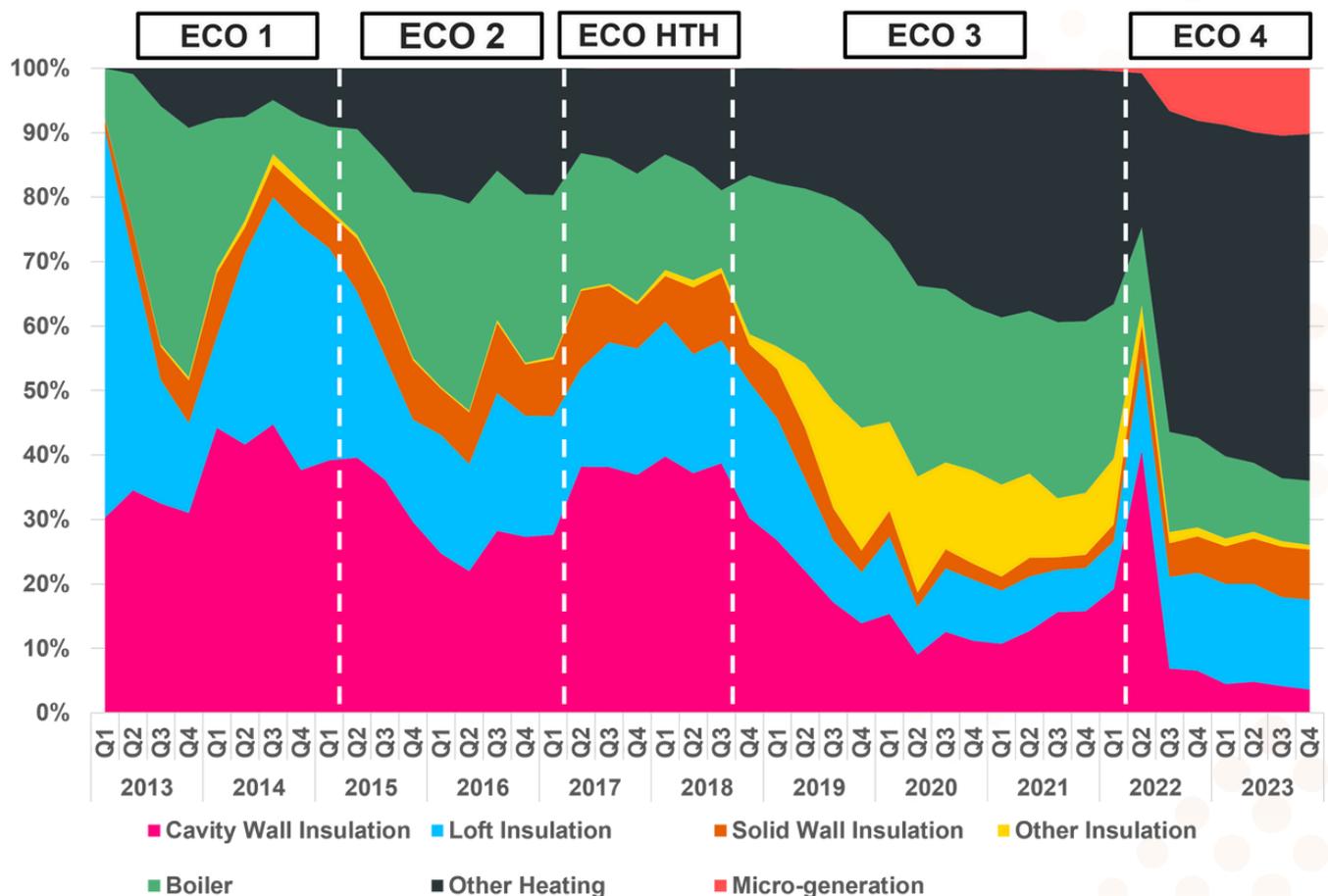


Figure 13 (c)

Figure 13 (a) Annual Energy Efficiency measures installations to 2023, (b) share of all measures installed by measure type, by scheme, and (c) share of quarterly ECO measures by measure type (with permission of DESNZ, (2024)).

According to DESNZ, up until 2023, just 9% of households in Great Britain had an ECO measure installed. Of the 3.81 million ECO measures, the Northwest region is the highest beneficiary installing 18%, followed by Yorkshire and The Humber (13%). Northeast, East, London, Southeast, Southwest and Wales each had the lowest share, accounting for 6% in each region. To the end of 2023, it is estimated that LAD (1-3), HUG1, GHGV and SHDF (wave 1) resulted in:

- Estimated annual energy saving of 291.6 GWh
- Estimated annual carbon saving of 0.0578 MtCO₂

To the end of March 2022, it is estimated that ECO and GD schemes (DESNZ, 2024) resulted in:

- Lifetime energy savings of 224,400 GWh
- Lifetime carbon savings of 60 MtCO₂.

Current Retrofitting Rate

Data on the current rate of whole-house retrofits is difficult to come by, and as such, assumptions must be made to infer current RRs. According to DESNZ (DESNZ, 2024) between April 2022 and August 2024, 202,100 WHR were completed under ECO4,⁶ this represents an average retrofit rate of 86,614 WHR per year since the beginning of ECO4.

This is 6% of the 1.4 million per year required retrofitting rate previously stated in this report [document](#).

Roughly 4.1 million measures were installed in 2.7 million households under the different funding schemes from 2013 to 2023 (DESNZ, 2024), resulting in an average of 1.1% homes receiving 1.5 funded measures, Figure 13(a).

When looking at 2022, this rate decreased to 0.40%. However, due to their nature of shallow measures, these rates should not be considered within the retrofitting rate (RR).

Only ECO4 started implementing the WHR approach, increasing the number of measures per home but decreasing the number of households receiving retrofitting measures. When looking at first-time households receiving ECO4 measures, the annual RR in 2023 can be estimated at 0.20%.

This is far from the RR needed to meet the target and discussed previously within this report ([Retrofitting rate targets](#)).



The UK must increase the national retrofitting rate by a factor of 16

⁶ Limitations with available data means that we must assume all homes completed under the ECO4 scheme equate to WHRs, the true number may be less due a number of ECO homes having previously been upgraded with other government scheme and not counting as WHRs.

Remaining potential by measure and dwelling type

To stimulate the adoption of Manufacturing-Led approaches, it is fundamental to better understand the production targets per measure or system to improve forecast pipelines. Data on the remaining potential by primary measures are lacking, inconsistent or provide insufficient information to build accurate understanding on the dwelling's performance.

The sources of data used for this chapter were:

- [The Household Energy Efficiency](#) Great Britain, Data to December 2023. Statistical Release, (DESNZ, 2024), and [Household Energy Efficiency Statistics](#).
- England Housing Survey data 2023-2024.

The remaining envelope's energy performance upgrade (insulation) potential.

Increasing insulation reduces the heating demand, enhancing the dwelling's energy performance.

The standard insulation measures are:

- Cavity or non-cavity (mainly solid wall) insulation
- Loft insulation
- Double glazing

a) Current understanding on the remaining insulation potential by nation.

DESNZ provides an estimation of the average insulation level within the UK's housing stock. Figure 14 illustrates the magnitude of remaining insulation potential within the UK's housing stock (Ministry of Housing, Communities and Local Government, 2023), the key takeaways from this are:

- 3.8 million easy-to-treat cavity walled homes
- 5.6 million easy-to-treat lofts.

Following an extensive literature search, the authors found no data currently exists for cavity walls that would need to be retrofitted.

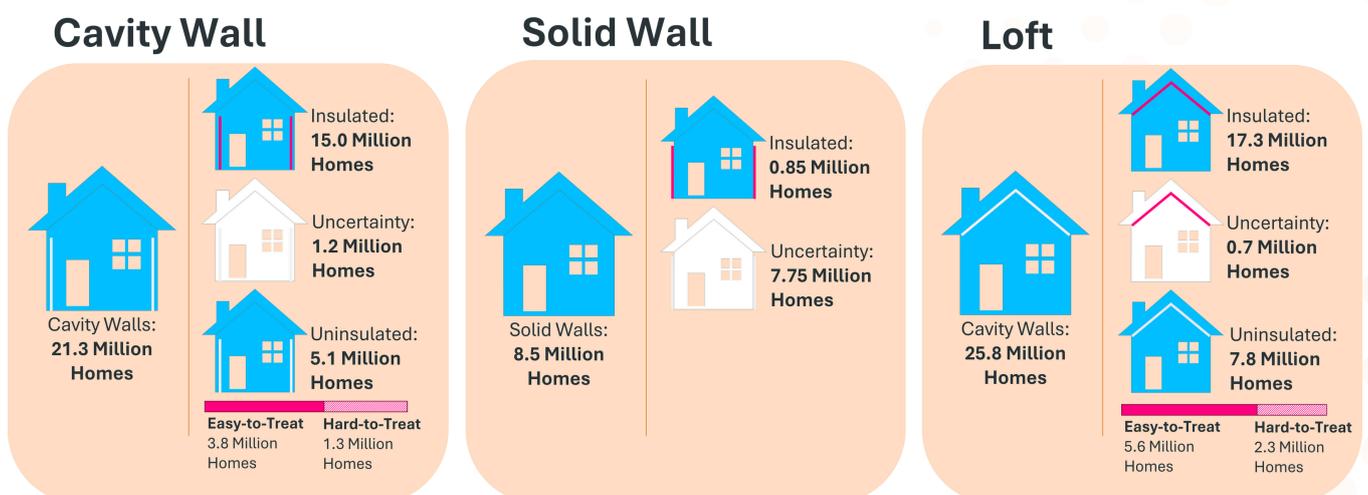


Figure 14: Remaining insulation potential in Great Britain, end December 2023 (based on: DESNZ, 2024).

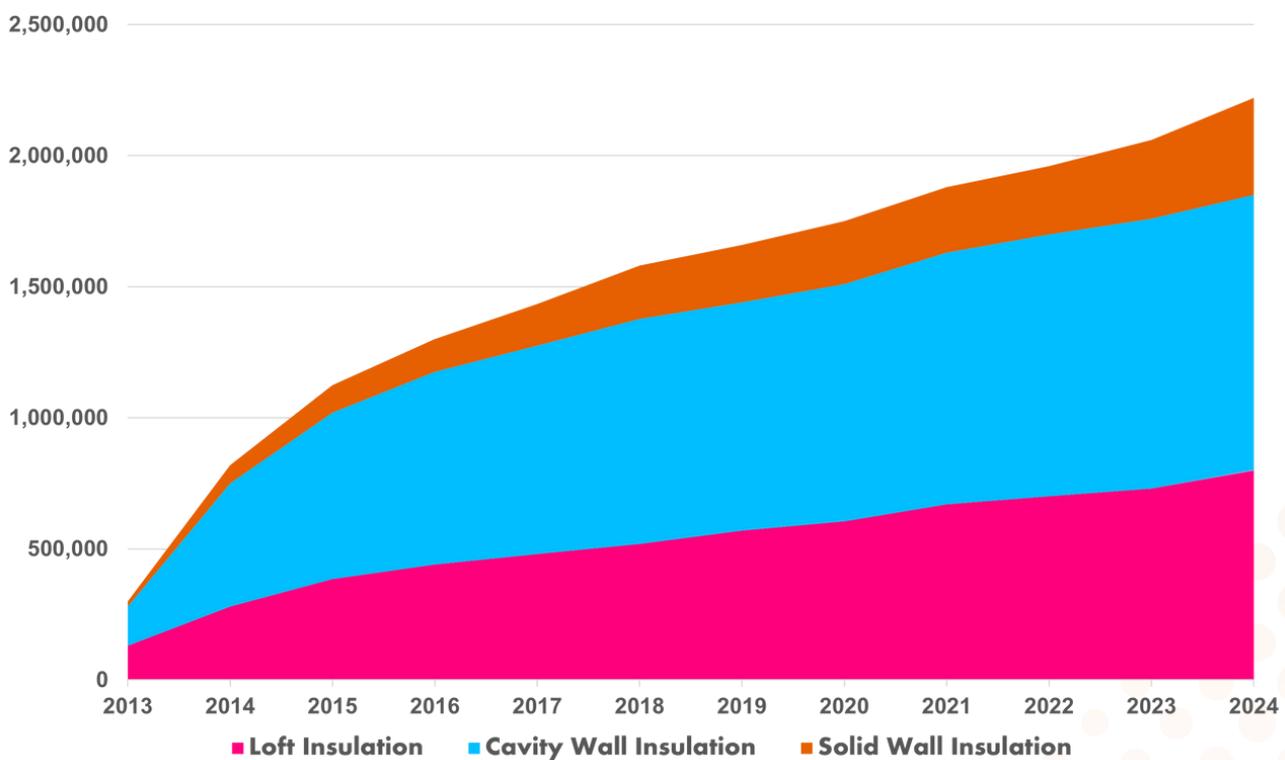


Figure 15: Cumulative professional insulation measures installed (y-axis) through Government energy efficiency schemes 2009-2023. (With permission from: (DESNZ, 2024)).

All measures shown in Figure 14 have increased since 2009, as seen in Figure 15, resulting in estimated lifetime carbon savings of 45 MtCO₂e since 2013, primarily due to the ECO initiatives.

Cavity wall insulation measures made through ECO initiatives alone resulted in lifetime carbon savings of 24.6 MtCO₂e (41% of overall measures' savings) and 96.5 GWh (43% of overall measures' savings) (DESNZ, 2024).

These values vary when the estimations are revised by nation, Scotland being the nation with the highest level of insulation, Figure 16.

Scotland's performance is due to a higher share of insulated properties pre 2013 and greater uptake of government funding schemes until 2023. Northern Ireland data (NIHCS, 2016) states that, in 2016, from all cavity walled homes, 65.3% (510,000 homes) had fully insulated cavities, 14.8% (116,000 homes) had partial wall insulation, internal, external and/or dry lining insulation, and 19.9% (155,000 homes) had no insulation.

In Northern Ireland, only 1.1% of lofts are uninsulated, while 54.2% are insulated with more than 150mm of insulation.

b) Hard-to-treat and easy-to-treat scenarios

DESNZ and the EHS differentiate the remaining insulation potential by hard-to-treat or easy-to-treat. Hard-to-treat does not refer only to technical difficulties but includes tenancy-derived complications (e.g. flats with multiple leaseholds) or high costs.

Table 4: Situations in which the wall might be hard-to-treat according to the (EHS, 2022) summarises the situations in which the walls and lofts can be "hard-to-treat".

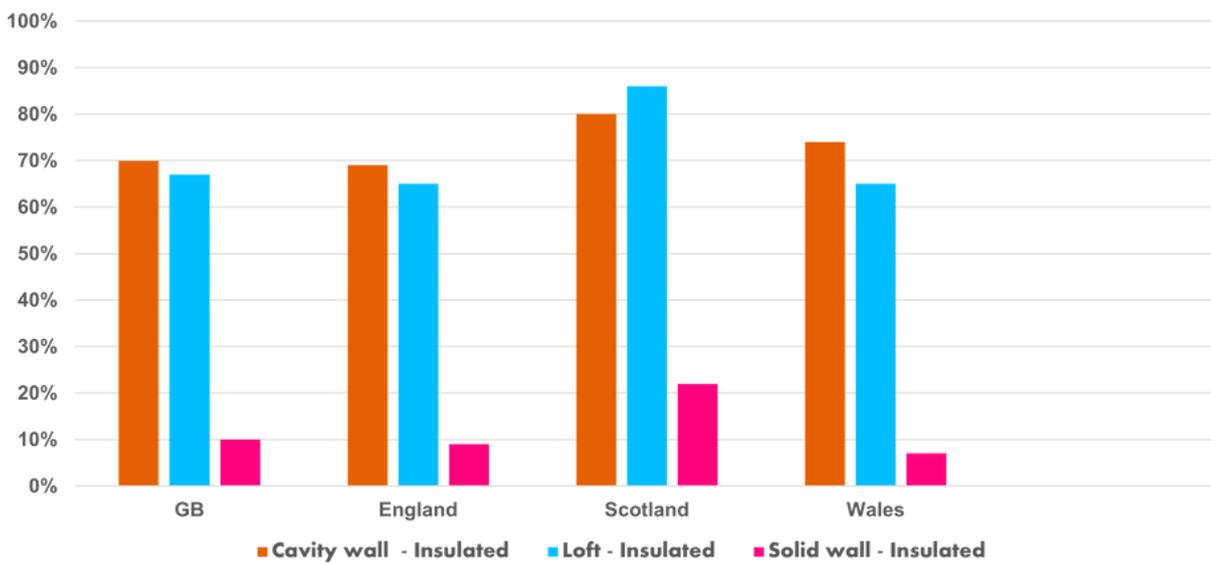


Figure 16: Homes insulation for GB, England, Scotland and Wales. (Based on (DESNZ, 2024)). Data shown as the share of insulation per construction type.

Table 4: Situations in which the wall might be hard-to-treat according to the (EHS, 2022).

Cavity wall insulation	Solid wall insulation	Loft insulation
<ul style="list-style-type: none"> • More than three storeys • Narrow cavities (<50mm) • Concrete, metal or timber frame • Predominant tiles or cladding • Wall finish is in state of disrepair • Exposed positions • Stone wall (uneven cavity) 	<ul style="list-style-type: none"> • Non-cavity wall with external features • Predominant render wall finish • Predominant clad or stone (non-masonry finish) • Dwelling is a flat 	<ul style="list-style-type: none"> • Pre-existence of boarded loft • Habitable room • Shallow pitch • Flat roof

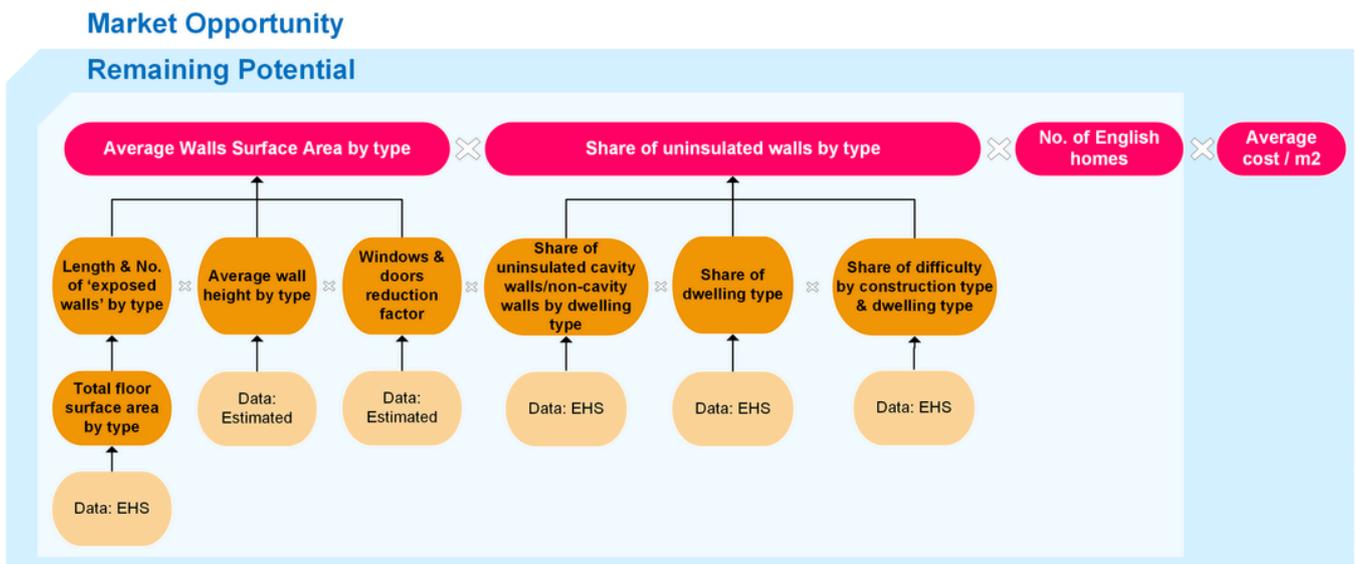


Figure 17: Process for estimation of remaining wall insulation potential and market opportunity.

Envelope's energy performance upgrade (insulation) potential in England

DESNZ estimates⁷ the number of homes with potential to receive cavity wall, loft or solid wall insulation in the future (DESNZ, 2024), aiming to inform future policies. However, this approach falls short when attempting to forecast the market opportunity.

This Define the Need report provides an estimate of the current market potential for England based on the existing data sources and highlights the opportunity for novel approaches when forecasting the pipeline.

The selection of England was based on:

1. The greatest share of total UK housing stock
2. The poorest insulation level
3. The availability of data (EHS) on insulation level and barriers to insulate non-insulated properties by property type.

Wall insulation potential

Quantification process: Figure 17 above shows the process followed to estimate the remaining potential of insulating walls in England. This process was followed to provide an initial estimation of the market size.

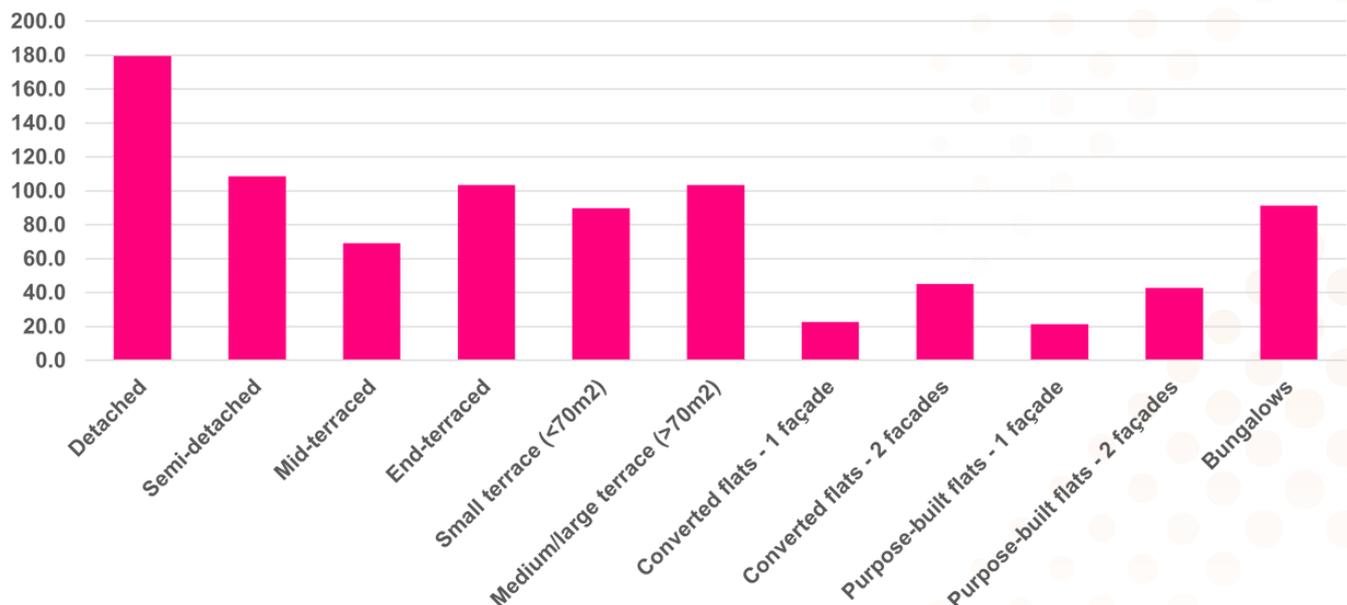


Figure 18: Estimated surface area of walls per building type.

The gross or total surface areas of the external walls – those to be retrofitted – per dwelling type have been calculated (Figure 18). The length of the façades was estimated by considering a square-shaped property using the **average total floor area** per dwelling type (MHC&LG, EHS, NSO, NatCen & BRE, 2018).

The number of external walls and average height was applied per dwelling property. Windows were taken into account by reducing the total surface area by 20%.

⁷ According to DESNZ, more detailed data are available in [Tables 8.4-8.6](#) of the accompanying Excel tables of the 2023 release. The detailed data from these tables in subsequent releases have not been made available.

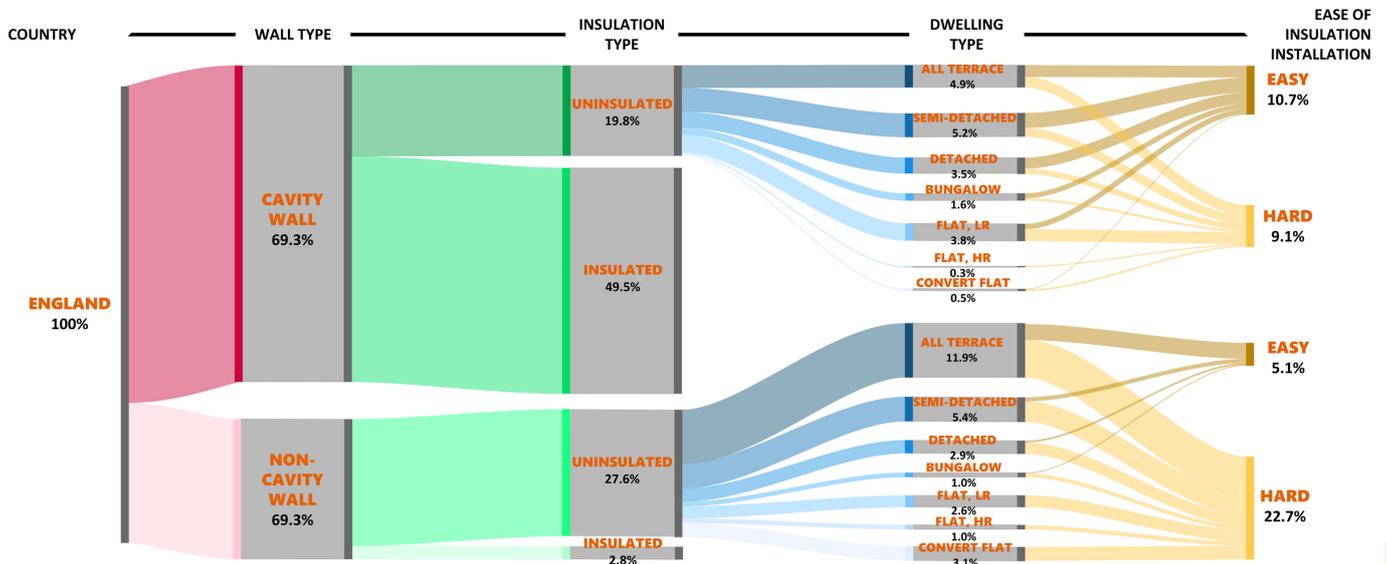


Figure 19: Estimations of remaining insulation potential of the English housing stock by wall type, insulation, type of dwelling and difficulty of retrofitting. Values represent the percentage of total homes in England. Data source: (DLUHC, 2022; DLUHC, 2023).

Results: The Sankey diagram in Figure 19 illustrates the distribution of homes with insulated walls across the different dwelling type in England, while Figure 20 provides the values per English region. Data refers to the housing stock from 2022, however the data aggregated by difficulty was last available in 2020.

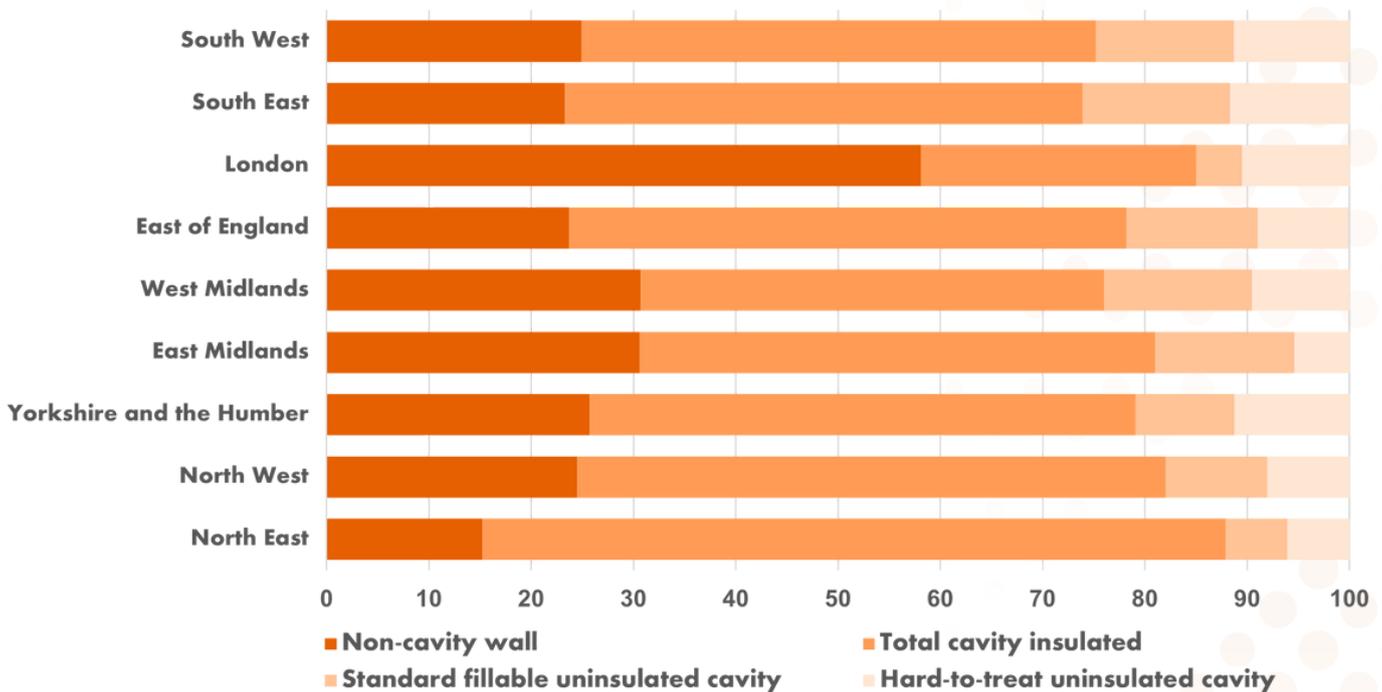


Figure 20: English cavity walls (in orange): insulated and uninsulated divided by 'standard fillable' and 'hard-to-treat' by share of regional total.

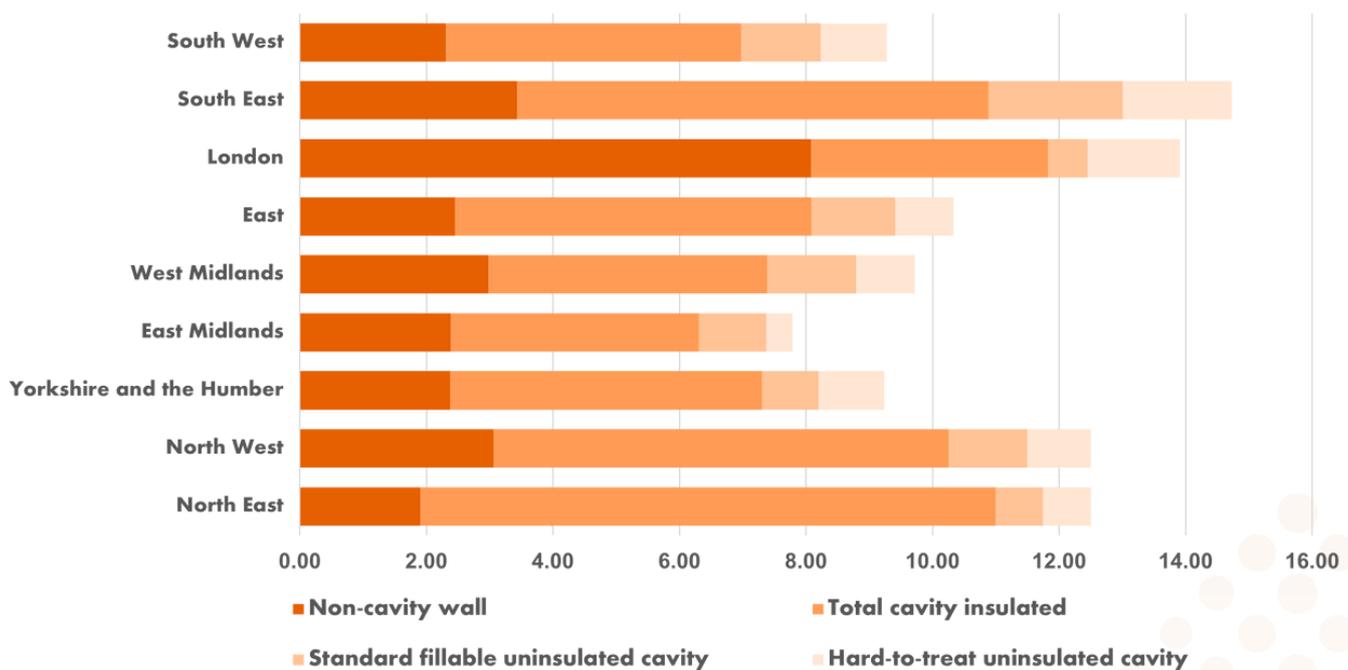


Figure 21: English cavity walls (in orange): insulated and uninsulated divided by 'standard fillable' and 'hard-to-treat' by share of the national total. (Data: (DLUHC, 2022)).

Cavity walls: About 70% of total English homes have cavity walls of which 29% are uninsulated. Around 54% of homes with uninsulated cavity walls (11% of total English homes) are easy-to-treat or standard fillable, while the remaining 46% (9 % of total English homes) are hard-to-treat (Figure 20 and Figure 21).

Around 300 Million metres squared (Mm^2), (61%) of cavities have the potential of being filled easily, while 190 Mm^2 (39%) would be more difficult or expensive- to-treat, see Figure 22(a). The lower share of hard-to-treat cavities is due to a greater share of flats (with less surface area of wall per property) being classified under this circumstance. Conversely, semi-detached homes represent a major opportunity for filling cavities that are not hard-to-treat, followed by detached homes.

This is particularly interesting from a solutions provider perspective since these properties are those with more wall surface area. It is estimated that there is a remaining potential of 91 Mm^2 and 106 Mm^2 of easy-to-treat cavities in semi-detached and detached homes, respectively, Figure 22(a) Figure 22(b).

Dwelling age can give an indication of the potential difficulties. Homes built before 1919 have a higher proportion of hard-to-treat cavities (62%) compared with homes built at any other time except those built between 1945-1964.

The former is predominantly due to restrictions placed on listed buildings, while the latter is likely due to non-traditional dwellings and impact of insulating the cavity may have on the structural frame, [see Table 4](#). The share of dwellings with hard-to-treat uninsulated walls reduces to 36% for those homes built after 1981 (DLUHC, 2022).

In terms of geographical distribution, the Southeast has the greatest number of cavity walls and thus has major potential for easy-to-treat cavity walls (520,000 homes). Northeast, with 73% of homes containing insulated cavity walls, represents the greatest share (9.1%) of this type in England.

London has the lowest share of cavity walls (32%) of which 70% of the overall uninsulated walls are hard-to-treat due to a higher presence of flats and pre-1919 dwellings. The remaining potential for easy-to-treat cavity walls in London entails the 0.6% (150,000 homes) of total homes in England Figure 21(b). East Midlands has fewer hard-to-treat uninsulated cavity wall homes due to the greater prevalence of detached homes in this region.

It must be noted that these estimations consider data up to 2022, therefore, they do not consider the properties retrofitted through government schemes or new builds with better insulation from 2023.⁸

- **2.7 million** homes have **easy-to-treat** uninsulated cavity walls, with an insulation potential of **295 Mm²**.
- **2.3 million** homes have **hard-to-treat** uninsulated cavity walls, with an insulation potential of **191 Mm²**.
- At least **1.4 million** semi-detached and detached homes could be suitable for **standard fillable insulations**, resulting in an insulation potential of **197 Mm²**.

Non-cavity walls: Non-cavity walls are predominantly masonry and stone solid walls but also include a minority of non-traditional homes with walls of timber, concrete and metal frames, or are of modular construction (DLUHC, 2024). More than 7 million (28%) of total English homes have non-cavity walls, of which 85% to 90% are uninsulated (DESNZ, 2024; DLUHC, 2022).

More than 18% of homes with uninsulated non-cavity walls (5.1% of total English homes) are easy-to-treat, while the remaining 82% (22.7% of total English homes) are hard-to-treat, [see Figure 19](#).

Around 180 Mm² of non-cavity walls are easy to insulate while 630 Mm² would be difficult or expensive-to-treat. Terraced homes entail the greatest share for uninsulated homes (11.9%) with 1.95 million homes with hard-to-treat walls and 0.84million homes with easy-to-treat walls, [see Figure 22\(b\)](#).

The barriers for non-cavity walls are i) the dwelling being a flat, ii) the dwelling having a predominantly rendered wall finish (half of solid wall homes built between 1919 and 1944 have rendered wall finishes), and iii) dwellings having external features, (with greater extent for older homes, especially those built before 1919) - [see Figure 23](#).

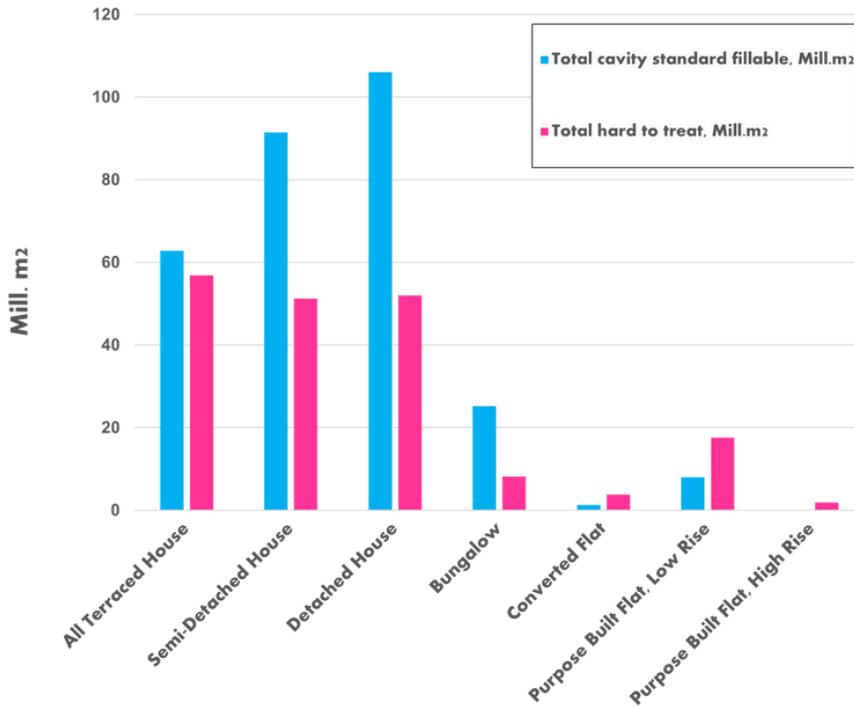
In terms of geographical distribution, London has the highest share of non-cavity walls (58%), 2 million homes within that region alone, of which 90% might need insulation. The Northeast has the lowest number of non-cavity walls due to its greater prevalence cavity walls.

It must be noted that this data does not consider the push for cavity wall insulation done by ECO3 and ECO4 schemes since 2023. Up to the end of 2023, roughly 63,500 solid wall and solid wall alternative insulation measures were installed under the the Solid Wall Minimum Requirement (SWMR) sub-obligation. 90,000 measures are expected to be installed under ECO4.

⁸ DESNZ estimates that around 210,800 more homes had cavity wall insulation in Great Britain, of which 17,600 (8.3%) were retrofitted while the remaining 91.7% were through new build. These data do not consider the insulation measures delivered in Scotland under the Green Homes Cashback scheme.

- Almost **1.2 million** homes might have **easy-to-treat** uninsulated non-cavity walls, with an insulation potential of **180 Mm²**.
- **5.3 million** homes might have **hard-to-treat** uninsulated non-cavities, with an insulation potential of **630 Mm²**.

(a)



(b)

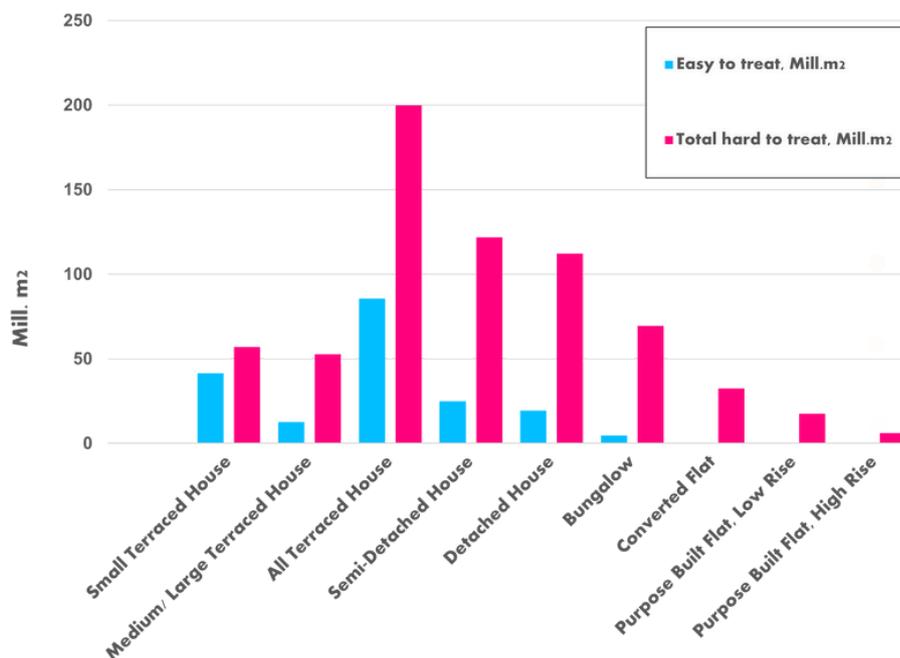


Figure 22: Estimated surface area in m² of remaining insulation potential by dwelling type and difficulty. (a) uninsulated cavity walls, and (b) uninsulated non-cavity walls.

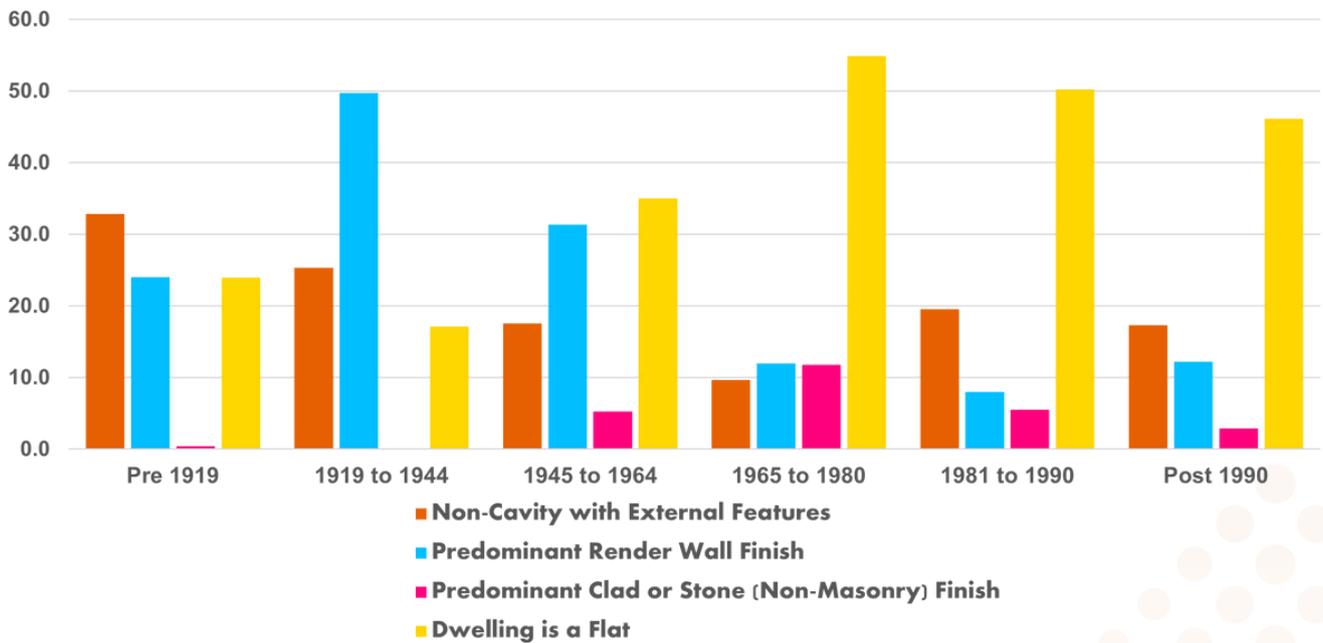


Figure 23: Main barriers to easily insulate non-cavity walls per age range (data source: DLUHC, 2023).

Loft insulation

Quantification process: the surface area of insulation for pitched roof was estimated from the floor area of homes. The surface area of open gable roofs having a pitch of 15° and 35° was considered and the average value was calculated. An off-set factor was applied to account for the reduced area of the internal insulation. Flats were excluded from this approach due to insufficient data.

Results: In 2022, 73% of homes (18.4 million) had a loft, while the remaining 27% were classified as ‘flat roofs or unknown’ and ‘no lofts’. Different insulation depth can be found in properties, depending on the recommendation of the applicable building regulations during the construction, as shown in Figure 24.

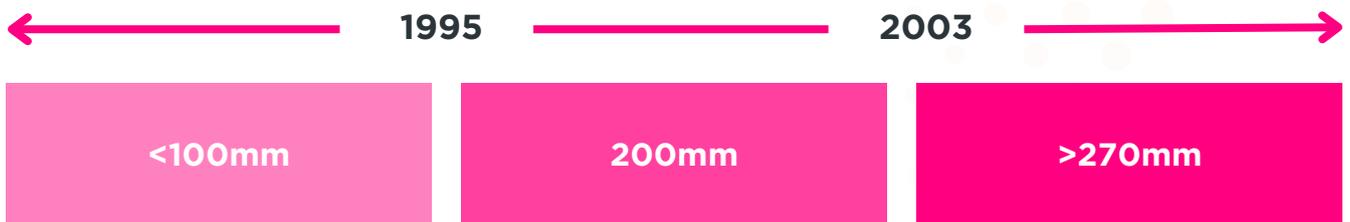


Figure 24: Thickness insulation recommended by Building Regulations over time

Around 9 million homes (49%) had loft insulation thicker than 150mm, 3.3 million homes (18%) had a thickness of between 100-150mm, and 1.1 million homes (6%) had a thickness below 100mm. There are at least 340,000 homes with uninsulated lofts.

Up to a quarter of the heat in the house could escape through the roof. The government recommends upgrading all homes with less than 270mm. However, the current available data makes it difficult to estimate the number of homes under this situation. According to the data, there are at least 4.4 million properties with less than 150mm of insulation, thus needing insulation or an upgrade.

In 2022, up to 1.3 million homes with 150mm or less, flat roofs with 100mm or less, or converted lofts were considered to be hard-to-treat while 3.7 million homes are non-problematic. The barriers that make a property's roof hard to insulate were i) the presence of boarding over the joists (43%), ii) a room in the roof (33%), and iii) a flat or shallow pitch (24%) (DLUHC, 2022).

Figure 25 illustrates the estimated remaining potential for loft insulation in houses, excluding flats. Non-problematic terraced, detached and semi-detached houses entail the greatest opportunity of 280 Mm² of potential loft insulation retrofits in England.

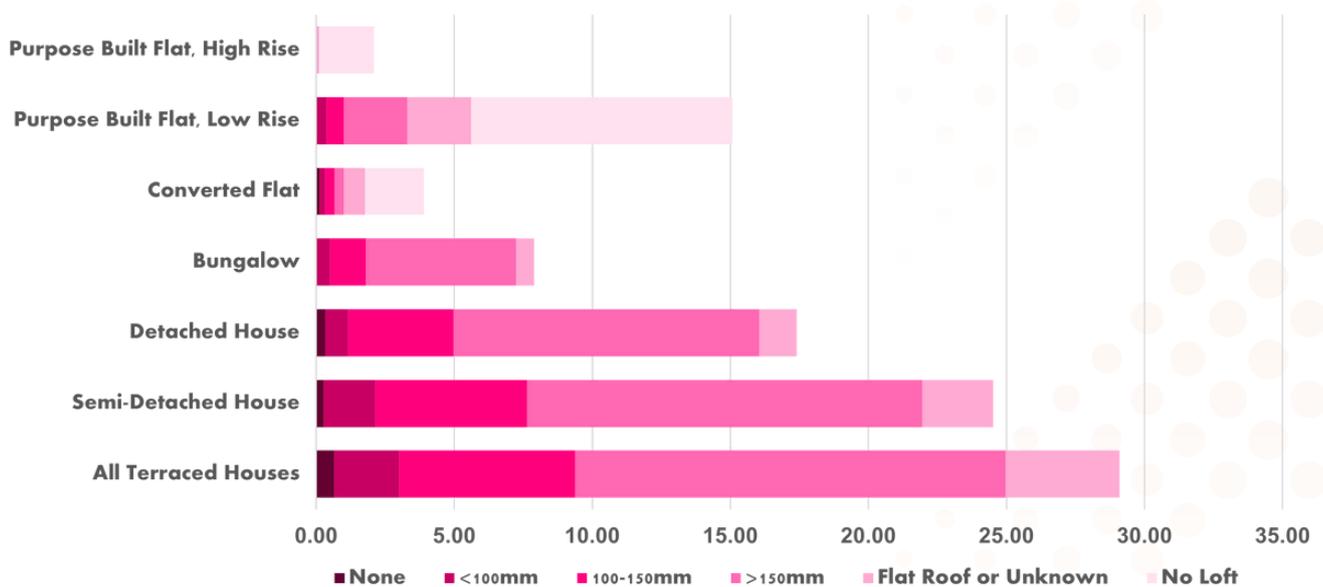


Figure 25: Loft insulation level by dwelling type. Values provided as share (%) of total UK homes.

In terms of regional distribution, homes in the Northeast (49%) and Yorkshire and the Humber (38%) were more likely to have hard-to-treat lofts than other regions (16%-31%).

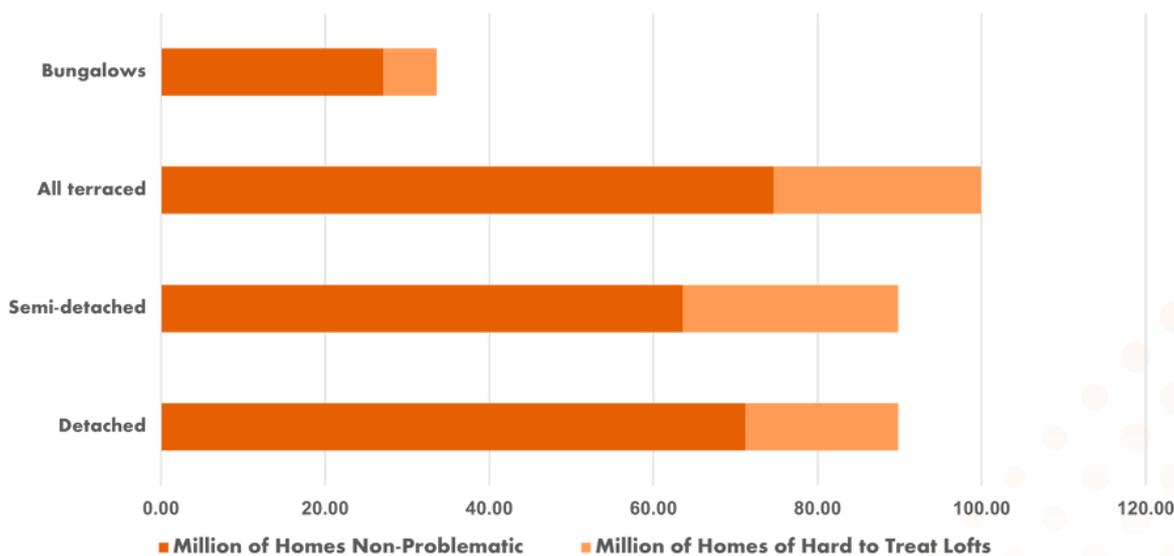


Figure 26: Average surface area of insulation of pitched roofs with existing insulation < 150mm.

- Almost **1.3 million** homes might need to insulate or upgrade their lofts.
- A surface area of **237 Mm²** of lofts in England are estimated to be **non-problematic** and **77 Mm²** are harder to insulate.

Floor insulation

Due to the difficulties in getting this information, it is common that the floor insulation is “assumed” in surveys such as those for EPC reports. The EHS do not provide this information. Looking at the construction type and age, an approximation can be achieved, as illustrated in Figure 27 below.

Double glazing

Up to 87.7% of properties have double glazing installed in the whole property, 6.4% and 3% were reported to have double glazing in more than half and less than half of windows, respectively, and only 2.9% of properties do not have double glazing. However, these data are inadequate to characterise the energy performance of these components due to missing information on age, thickness, type of frame, etc.

Floor configurations change depending on the construction period (NHBC, 2015). Insulated floors were rare before 2000s, resulting in only 3 million properties having floor insulation and more than 50% of homes having rising damp through brick foundation or ground floors. Until the end of the between-wars period, floors were suspended (45% of total properties), and ground floors with damp-proof membranes were installed from the 1960s.

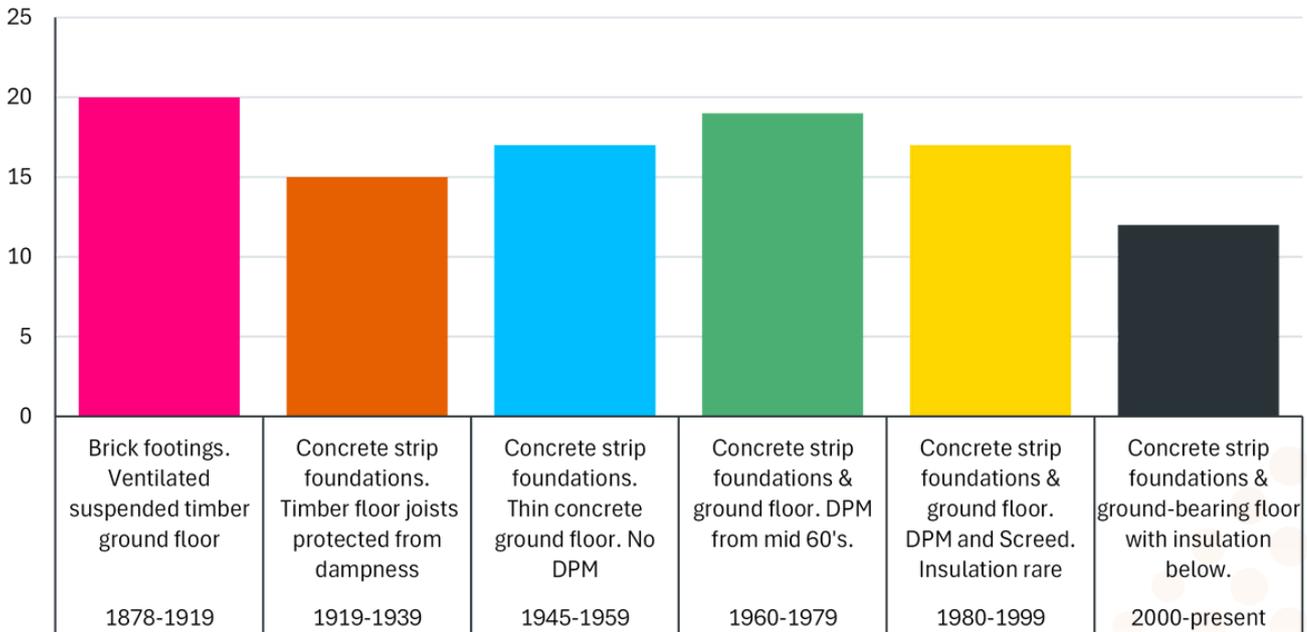


Figure 27: Approximate characterisation of housing floors. DPM stands for Damp Proof Membrane (Data from: (NHBC, 2015; EHS, 2024).

Limitations of this procedure

The data from the EHS are very valuable in providing a high-level characterisation of the housing stock, however, they do not provide enough information to assess the building performance and efficiency of existing measures since this is not an EHS objective. For instance, the real extent of the insulation is unknown, since the EHS considers a house to have insulated walls if at least 50% of the walls are insulated, and there is no mention of thermal bridges.

Data on wall insulation does not provide basic and key information on the thickness, the type and thermal conductivity of the insulation material. Furthermore, it is worth questioning whether the performance of old insulation has been compromised over the years, particularly in cavities, and may need to be revisited and upgraded.

The insufficient characterisation of housing stock data to gain an accurate understanding of the energy performance is applicable to the rest of the components (loft insulation, glazing, floor insulation). This implies the need for tools and methods to better capture real data when designing solutions.

The remaining space low-carbon heating potential

Table 5: Heating systems/source by nation expressed in total quantities, nation share and overall UK dwelling stock share.

		Total	Percentage	Percentage of Dwelling Stock
ENG	Gas Fired	21,942,889	87.3%	73.8%
	Oil Fired	892,384	3.6%	3.0%
	Solid Fuel	6,1254	0.2%	0.2%
	Electrical	2,256,532	9.0%	7.6%
SCO	Mains gas	2,058,000	80.7%	6.9%
	Electricity	277,000	10.9%	0.9%
	Oil	130,000	5.1%	0.4%
	Communal Heating	34,000	1.3%	0.1%
	LPG bulk or bottled	27,000	1.1%	0.1%
	Solid mineral fuel	12,000	0.5%	0.0%
	Biomass	12,000	0.5%	0.0%
WAL	Gas Fired	1,120,500	87.9%	3.8%
	Oil Fired	128,250	10.1%	0.4%
	Solid Fuel	-	-	-
	Electrical	25,650	2.1%	0.1%
NI	Gas	186,010	24.1%	0.6%
	Oil	526,160	68.1%	1.8%
	Other	61,050	7.9%	0.2%
Total		29,750,679		100.0%

As reported by the UK housing surveys, 85.47% of the UK dwelling stock is fuelled by fossil fuel systems. England, Scotland and Wales all surpass the 80% of homes having gas fired systems, while Northern Ireland's main heating source is oil, as shown in Table 5.

To reduce the CO₂ emissions from heating homes, all households using fossil fuels or inefficient heating systems must switch to low-carbon alternatives such as heat pumps or low-carbon heat networks - both technologies considered by the government to play a key role in the years to come (HM Government, 2021).

a) Current delivery and projections

With the national aim for all new heating systems in homes to be low-carbon, and all homes being net zero by 2050, there is a need to scale up the production and adoption of low-carbon heating systems such as heat pumps.

The government is aiming to ban the installation of gas boilers in new homes by 2026 and significantly reduce the installation of new gas boilers in existing homes by 2035. This doesn't mean an outright ban, but a push towards more energy-efficient and low-carbon heating solutions.



The CCC estimates an additional investment of £162 billion is required from 2020 to 2050 for installing low-carbon heating in existing UK homes.

The Department for Energy Security & Net Zero (DESNZ) has a target of 600,000 heat pumps to be installed annually by 2028 and reach 1 million and 1.6 million installations per year in 2030 and 2035, respectively.

This entails a challenging ramp up of more than 11 and 18 times the current rate, estimated at 55,000 heat pumps sold in the UK in 2022 by 2028 and 2030 (NAO, 2024). Similar estimates are provided by the CCC who project that 15.3 heat pump installations per 1,000 people per annum will be needed to meet the UK's 2050 net zero targets.

At the current installation rate, achieving this target could take over 600 years (CCC, 2020).

According to the Energy & Utilities Alliance, up to 54% of the UK's housing stock would be unsuitable for a heat pump only solution (Energy & Utilities Alliance, 2021)⁹. Alternative options such as biofuel combustion and heat networks may need to be provided to these properties.

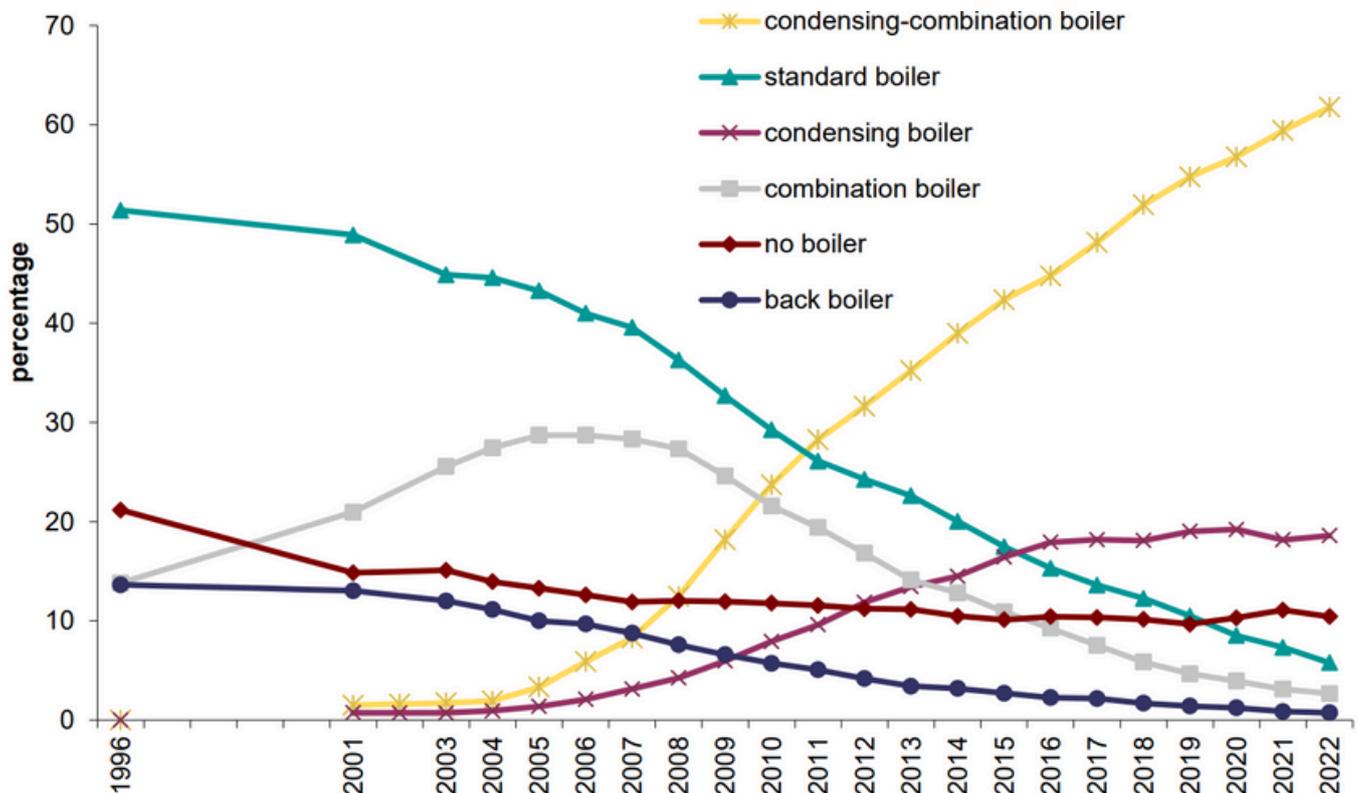


Figure 28: Boiler types 1996-2020 sourced from (EHS, 2023).

⁹ The viability of different archetypes for heat pump installations is not very well understood with no broad consensus on what makes a property viable for heat pump installation.

When scaling up, the real efficiency of existing boilers needs to be taken into consideration also. Older and inefficient boilers such as standard boilers should be replaced first, followed by older and inefficient condensing/condensing-combination boilers, see Figure 28 above, however in both cases CO₂ payback from early scrapping is short (1-2 years).

The challenge is not only capturing accurate data, but also making the decision since this feature might be highly variable from home to home.

b) Barriers to meeting the targets

The National Audit Office, point out a list of barriers and uncertainties when auditing DESNZ that may put the current target under risk. Some of these are:

- Installation costs need to reduce by at least 25-50% by 2025 compared to 2021. The current reduction (6% since 2023) falls short due to pressures in the global supply chain (e.g. shortage of semiconductors, increased global demand, and increased manufacturing costs due to energy prices).
- Running costs need to be reduced.
- Lack of a long-term consumer engagement plan.
- Boiler Upgrade Scheme uptake is less than anticipated.
- A shortage of information on heat pump installations for DESNZ to monitor whether progress is on track and to identify key barriers to uptake.

c) Potential for innovation and transformation

The green energy transition will result in further development of low-carbon technologies looking not only at energy efficiency and emissions reductions but promoting circularity and resource efficiency of buildings.

For example, there is still huge potential for:

- Standardisation and certification of novel low carbon technologies, heat source materials and products.
- Further development of premanufactured 'plug and play' heat pump systems and compact heating/cooling plants.
- Development and standardisation of interfaces that enable the deployment and upgrading of 'plug and play' systems.
- Upgrade technologies for district heating networks.
- Continue development of thermal energy storage and micro-CHP/CCHP systems using renewable gases.
- New business models such as energy as a service, and incentivising innovation through the underwriting of emerging technologies.



Delivering the future of retrofitting

UK supply chain

In their ‘International review of domestic retrofit supply chains’ (BEIS, 2021), [BEIS](#) outlines several challenges for retrofit at scale in its main findings:

“Retrofit supply chains are fragmented. There are large numbers of small businesses, and several may be involved in any one retrofit project.”

“Generating homeowner demand for deep retrofits and developing the supply chain to meet this can take many years. There are no examples as yet where niche approaches have scaled up significantly or have become self-sustaining, financially.”

None of the countries reviewed within this report are delivering retrofit projects at the scale needed to effectively reduce emissions in line with global targets. The fragmented and small-scale nature of these projects presents the following challenges:

- Effective coordination across multi-disciplinary teams required to deliver retrofit programmes repeatedly and efficiently.
- Issues with quality control and assurance of retrofit measures.

Further to the findings by BEIS, in its review of the [UK Retrofit Skills Gap & Supply Chain Analysis](#), The Connected Places Catapult has modelled four scenarios for the ramp up of retrofit in the UK to meet net zero 2050 targets for the built environment. These scenarios and the associated targeted retrofits per year on average are summarised in Table 6.

Table 6: UK supply chain scenarios for retrofit. (Source: Connected Places Catapult).

Scenario	Stochastic supply chain model	Name	Target retrofits per year (average)	Probability of retrofitting 27 million homes by 2050
1	High productivity and high capacity	En route to net zero	1,242,000 homes	98%
2	Low productivity and high capacity	Sub-standard proliferation	1,046,000 homes	56%
3	High productivity and low capacity	Adept, but insufficient	1,022,000 homes	41%
4	Low productivity and low capacity	The brink of failure	826,000 homes	0.2%

Even in the worst-case scenario 4, as modelled by the Connected Places Catapult, the UK would need to have delivered roughly 1 million whole-house retrofits by 2030. Given that to date the UK has delivered 207,700 [deep retrofits](#) through ECO4 (DESNZ, 2024), clearly there is a significant jump required in UK supply chain capability and capacity to ramp up to meet net zero targets.

The acceleration in retrofit delivery highlighted by this data outlines the scale of the challenge for industry, government and wider society. Only a joined up, standardised and repeatable approach for the delivery of retrofit will achieve the ramp up required. This can only be realised by interventions such as streamlining the retrofit process, investment in skills, building supply chain capacity and capability, and moving towards a manufacturing approach.

Other key enablers have already been discussed, such as new models for finance, risk and insurance as well as increased collaboration in the innovation of products and processes and clear roles and responsibilities agreed at project initiation.

Why use the archetype approach? Definition and benefits of archetype.

Targeting a group of homes with common features or characteristics, represented by the 'archetype', can simplify and accelerate retrofitting projects. Based on the [Cambridge Dictionary](#), this report defines an archetype as:

A **typical example** of a property subject to energy rehabilitation measures.

The archetype is defined by a series of characteristics. All homes that share these characteristics can, by extension, be added to the pipeline and be subject to renovation with known expected outcomes.

The more characteristics defined, the greater the definition of the archetype, leading to greater similarity with the homes added to the pipeline but a smaller number of such homes.

An archetype should consider as a minimum 'dwelling type' and 'age'.

Defining an archetype in a retrofitting project can deliver benefits, such as:

a) Improved forecasting of the project pipeline

- **Predictable outcomes:** The potential results of retrofitting can be more accurately forecasted by defining an archetype. Homes that fit the archetype are expected to respond similarly to retrofitting measures, thus the outcomes become more predictable.
- **Scalable planning:** Archotyping allows estimation of the number of homes that share specific characteristics providing better forecasting of resources, budgets, and timelines, improving the efficiency in project delivery.

- **Prioritisation of projects:** Archetypes help in prioritising which homes to retrofit first. For instance, homes with well-defined archetypes that are easier to retrofit can be tackled earlier, ensuring quick wins and helping to allocate resources efficiently.

b) Modelling archetypes instead of all homes in the first instance

- **Cost-effective modelling:** Defining archetypes allows for a broader approach, where only a few representative models need to be analysed in-depth in the first instance to forecast the impact of retrofitting a group of homes. This does not discard any later requirement for bespoke modelling to gain a deeper understanding of cost.
- **Reduction in complexity:** Addressing homes with a shared archetype reduces the complexity of creating and applying retrofitting solutions. It eliminates the need to start from scratch for each home, thus streamlining the planning and decision-making processes.
- **Consistency:** By focusing on typical cases, energy savings and performance improvements can be standardised, leading to more reliable outcomes across the board, and allowing the retrofitting teams to follow proven protocols.
- **Enabling more private capital:** Standardisation enables private capital to flow more easily, unlocking the finance building retrofit desperately needs.

c) Selection of optimum targets and technical solutions

- **Targeted solutions:** By understanding the common construction materials, orientation, insulation levels, etc., teams can develop a set of best-practice interventions or select existing solutions that are technically and economically optimal for that type of property.
- **Compensation for variability:** The archetype approach recognises that not all homes will be able to achieve the same energy performance targets due to inherent limitations (e.g., age, structure). Using archetypes will identify which homes are easier to be retrofitted to higher standards, compensating for homes that face greater difficulties or higher costs.
- **Flexibility in implementation:** The archetype definition can be used to determine the number of homes that could be handled with standard technical solutions, and which may need bespoke solutions and approaches.

d) Data-driven decision making

- **Data collection & analysis:** When multiple homes are grouped under an archetype, it is easier to collect data on their performance, track progress, and refine models. This feedback loop enhances the decision-making process by providing a growing database of how similar homes respond to various retrofitting measures.

- **Learning from similar homes:** Once the performance of retrofitting measures is observed in one home, this information can be directly applied to others in the same archetype. The insights gained from pilot projects or early implementations improve decision-making and allow for continuous optimisation.

e) Facilitates stakeholder communication and engagement

- **Clear communication:** Defining archetypes provides a clear framework for communicating retrofitting plans to stakeholders, including homeowners, contractors, and policymakers.
- **Strategic partnership:** Utility companies, local governments, and financing institutions can more easily align with a retrofit project when there are clear archetypes.

This helps in structuring incentive programmes, securing funding, and creating policy initiatives that address the typical homes in a region.

What is the reduction target per home?

The current space heating demand profile of the UK existing homes modelled by The Passivhaus Trust and LETI (Figure 29) clearly shows that:

- The space heating demand is around 120-130 kWh/m²/year ranging from 80 to 190 kWh/m²/year.
- A typical UK new build (Building Regulations 2020) has a space heating demand of 85 kWh/m²/year.
- An average UK existing home will require a reduction on the space heating demand between 60% (AECB/LETI) and 80% (EnerPHit) to meet the different retrofit targets.

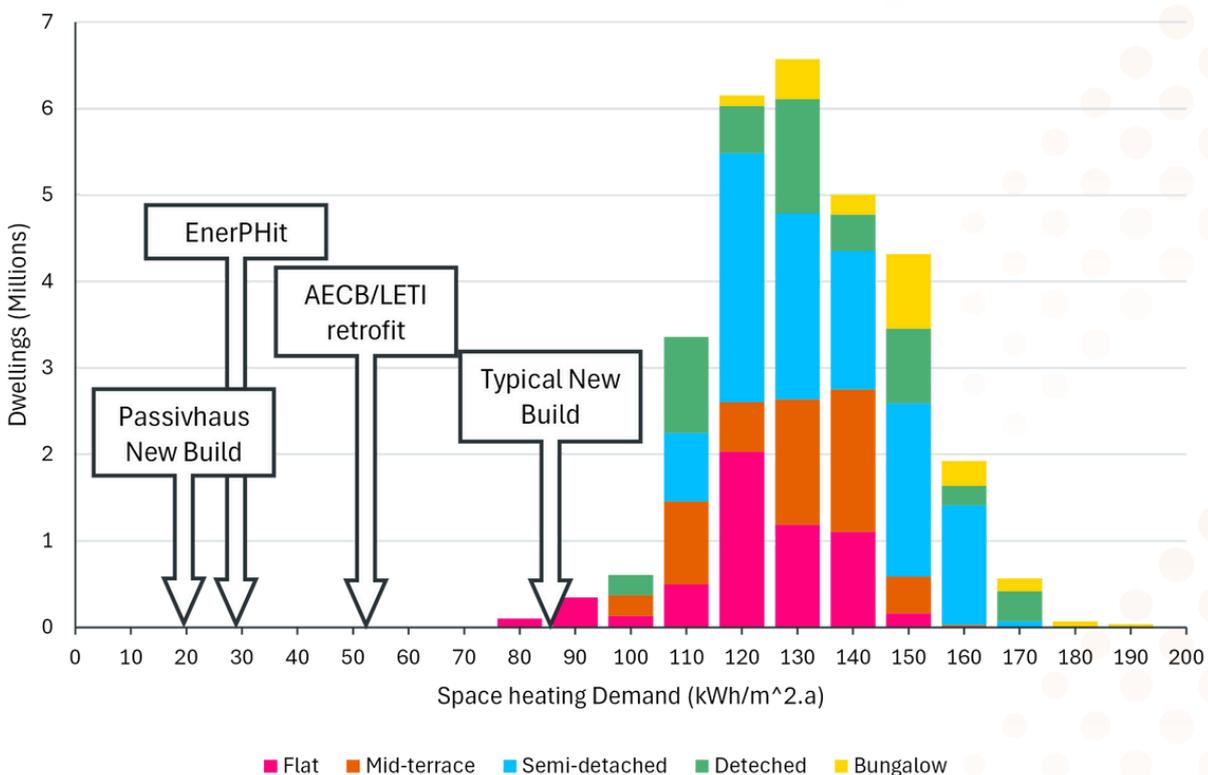


Figure 29: UK housing stock breakdown by space heating demand and dwelling type (based on data from Passivhaus Trust (Passivhaus Trust (2022)).

What target should be used?

It must be understood that, just as there is no optimal technical solution that applies for all scenarios, there is no single target that applies to all homes.

The physical characteristics (construction type, orientation, size, etc) will determine the solutions that have the greatest impact at the lowest cost.

Excessive cost for certain homes to reach a more demanding target will prevent retrofitting projects being funded. This is why homes that can achieve higher targets without difficulty should be identified and prioritised, to compensate for the limitations of homes that face more challenges.

What is the most suitable strategy?

When it comes to retrofitting, several strategies exist each with their own positives and negatives.

A broad overview of the main strategies can be found in [Appendix B](#), (Institute for Sustainability and UCL-Energy, 2012; NBS, 2023). To determine the strategy most suitable to the needs of a project, instruments such as the Value Toolkit, and Greenbook can be used to clearly identify the desired outcomes.

Projects should follow a holistic approach assessing the existing features of the building and delivering a planned retrofitting project based on the results of thorough assessment. It is imperative to move away from a set of shallow measures that are unlikely to meet the energy reduction targets, improve the comfort and may result in costly running systems and the appearance of undesired consequences such as mould formation (Passivhaus Trust, 2022).

The order in which measures are installed will impact lifetime emissions, for instance, installing heat pumps early can greatly reduce emissions very quickly, but would require planning and forethought to appropriately size the heat pump for future energy demand, and leave space for any fabric retrofit measure.

The project, supply chain, and funding accessibility circumstances will determine if the project is delivered as a whole-house retrofit or step-by-step project. It is unlikely that with the current capacity of the sector, whole-house retrofitting approaches could be applied to the forecasted 1.2 million homes per annum such as appointed by AECB, see Figure 30 below.

The prioritisation studies simplified by the analysis of archetypes will enable the selection of the most suitable pathways. Ideally, this analysis should be scaled up at a regional level supported by governmental strategic plans and policies.

As previously explained, we cannot rely on the decarbonisation of the grid nor the use of low-carbon heating systems alone. Only balanced and strategically applied plans will enable the success of the national retrofit challenge.

There is a need for defining suitable smart designs for retrofitting pathways to archetypes, which will only be achievable by collaborative approaches and relying on data-based decision making.

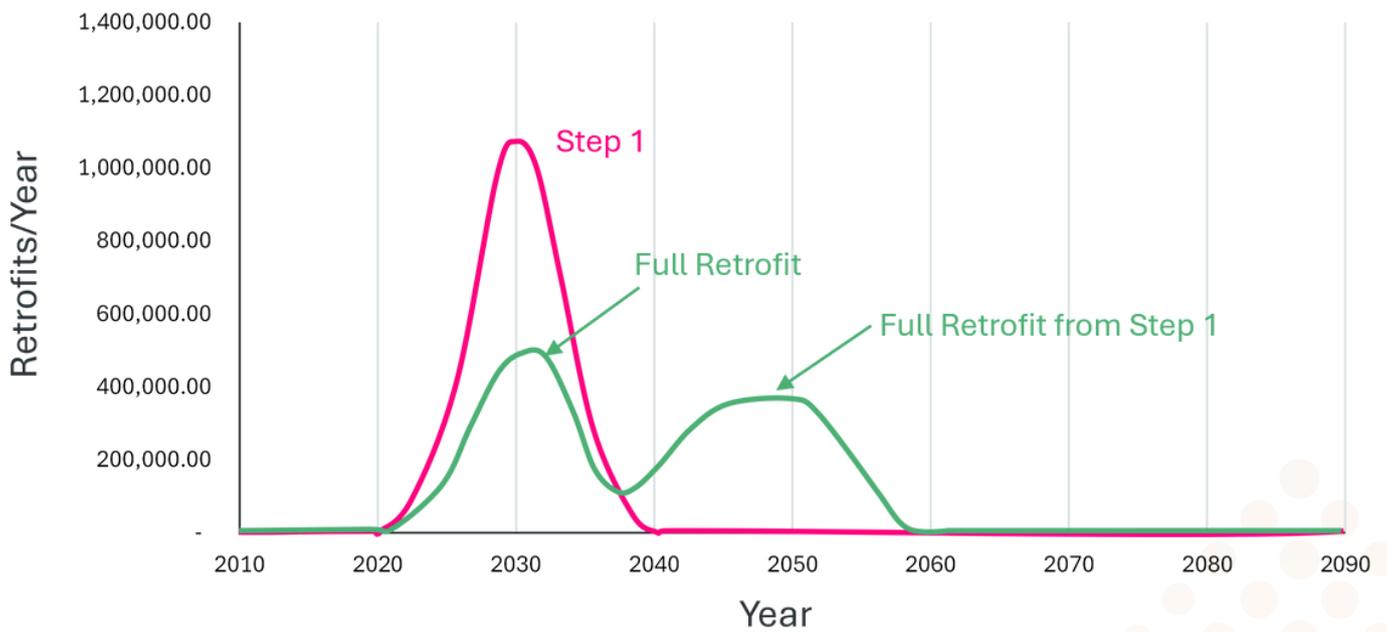


Figure 30: Example of a retrofit programme by AECB (AECB, 2024).

Step 4 - Harmonise requirements

To achieve a platform or Manufacturing-Led approach in the built environment, there are fundamental steps that need to take place first, as identified within the **DEMAND** phase of the CIH Rulebook framework. Standardising processes while allowing for customer variability enables mass customisation, through the development of interoperable kits-of-parts. As well as aggregation of demand to gain visibility of pipeline, another key step is the harmonisation of requirements.

For the Construction Innovation Hub, a core focus was to Harmonise, Digitise, Rationalise (HDR) requirements across schools, hospitals and other department buildings. This approach was adopted from The Construction Playbook, which guides government new build projects.



“Harmonising, digitising and rationalising demand will enable standardised, repeatable design, components and interfaces and drive the adoption of Modern Methods of Construction (MMC) including digital and offsite manufacturing technologies.”
(UK Gov, 2021)

“Contracting authorities should seek opportunities to collaborate in order to develop and adopt shared requirements and common standards. This should be done to enable standardised and interoperable components from a variety of suppliers to be used across a range of public works. This will create a more resilient pipeline and drive efficiencies, innovation and productivity in the sector.”
(UK Gov, 2022)

What does HDR mean for the retrofit market?

The core aim of HDR within the hub was to enable standardised offsite solutions, based on standardised government client requirements. Harmonising requirements ensures industry has consistent, common information.

Digitising enables data to be used effectively, and a digital thread of information to flow from requirements into construction of the built asset. Rationalising requirements removes wasted time and effort, through providing commonality of information of the pipeline demand.

Simplifying the pipeline of demand for retrofit means finding commonality of requirements and standards across the range of archetypes in the UK, as opposed to new build hospitals, schools and other government buildings. One example of a national effort to research HDR for retrofit, includes the pilot version of the [UK Net Zero Carbon Buildings Standard](#).

Below, we have provided a first pass for Transform-ER technical requirements, these will be updated in the Transform-ER Retrofit Rulebook.

Transform-ER focussed programmes

To enable the Transform-ER system to be developed against prevalent use cases within the UK housing stock, a high level down selection was completed to select property archetypes. These archetypes will form the base example cases to which outputs from the programme can be reviewed and tested against.

The four building archetype examples selected by the Transform-ER consortium were the following:

- 1920s -1940s solid brick council estate houses
- BISF (British Iron & Steel Federation) houses
- Wimpey No Fines houses
- 1920s - 1970s cavity wall houses.

The technical requirements of products and retrofit measures will be generated based upon the requirements for the four property types identified as the hypothesis specification.

Requirements harmonisation

Figure 31 below shows the categories as identified for Transform-ER performance requirements. These have been collated from consortium partners and input from the Construction Innovation Hub Define the Need report.

Within the Transform-ER project, core retrofit performance requirements have been categorised into:

- Level 1 – Core retrofit performance requirements
- Level 2 – Secondary performance enablers
- Level 3 – Wider industry regulations and standards.

[Figure 32](#) shows this in diagrammatical form.

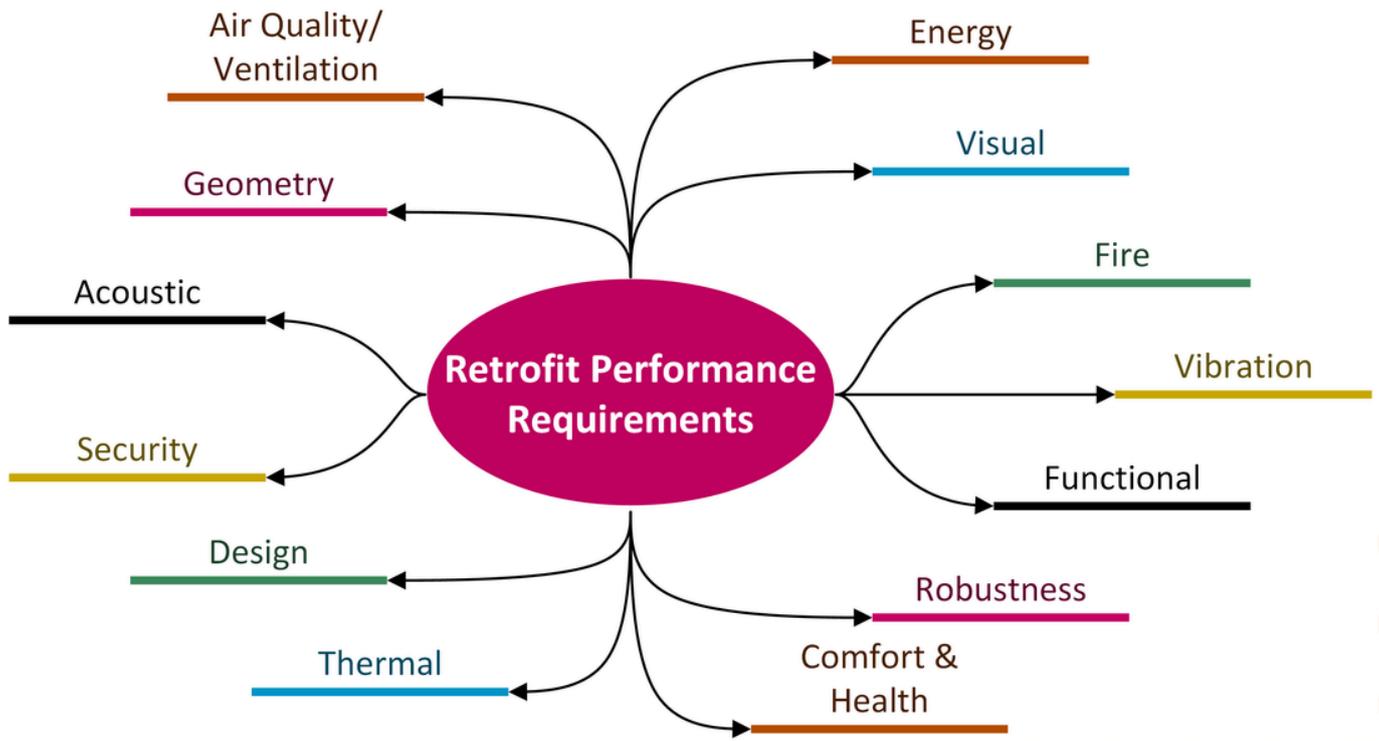


Figure 31: Context diagram illustrating the categories considered within the hypothesis specification.

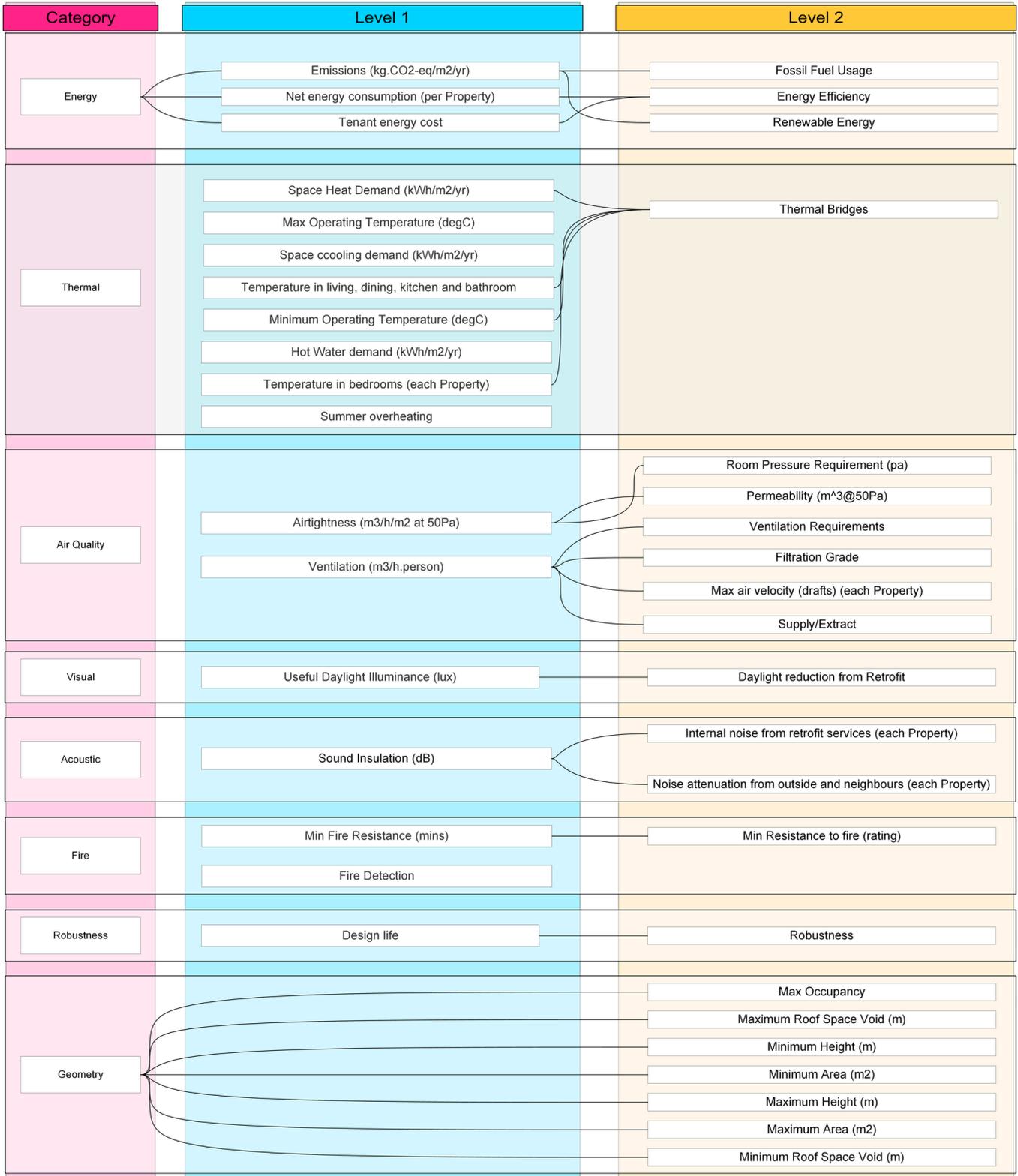


Figure 32: Illustration of Level 1 & 2 requirements, Level 3 requirements are not captured.

The requirements captured for Transform-ER were then used to derive an initial hypothesis specification. This is shown in Table 7 below.

Transform-ER hypothesis specification

Table 7: Hypothesis specification for the Transform-ER consortium.

Category	Performance Requirement	Hypothesis Specification	Source	Level 1	Level 2	Level 3
Energy	Fossil fuel	Reduce or Free	LETI Retrofit, AECB, EnerPhit, RIBA 2030 Climate Challenge		x	
	Emissions (kg.CO ₂ -eq/m ² /yr)	17 to 22	AECB, Retrofit for the Future	x		
	Renewable energy (PVP, % roof area)	> 40	LETI Retrofit		x	
	Methodology	PHPP	LETI Retrofit, AECB, EnerPhit			x
	Energy Efficiency (%)	TBC	To add from Define the Need		x	
	Net energy consumption (per Property)	Target: <1,500 kWh/yr; Minimum: <2,500 kWh/yr	ESUK, LETI Retrofit, EnerPhit, RIBA 2030 Climate Challenge	x		
	Current EPC Rating		Archetype / Portfolio specified (4 Transform-ER programs)			x
	Target EPC Rating	Minimum C	UK Government			x
	Tenant energy cost	Target: <40% pre-retrofit cost; Minimum: <pre-retrofit cost	ESUK	x		
Feedback and information provision	Provision of real-time and historical feedback to enable comparison	ESUK			x	
Thermal	Space heat demand (kWh/m ² /yr)	Target: <40 kWh/m ² /yr; Minimum: 50 kWh/m ² /yr	ESUK, DESNZ	x		
	Space cooling demand (kWh/m ² /yr)	≤15 to 25	AECB, EnerPhit, Superhomes, RIBA 2030 Climate Challenge	x		
	Hot water demand (kWh/m ² /yr)	20 to 25	LETI	x		

Transform-ER hypothesis specification

Category	Performance Requirement	Hypothesis Specification	Source	Level 1	Level 2	Level 3
Thermal	Hot water volume (per Property)	140 litres available per day. 140% of litres available per day delivered >45°C in one hour.	ESUK			x
	Thermal bridges (W/m ² K)	$\Psi \leq 0.01$ or $\chi \leq 0.04$	AECB, EnerPhit		x	
	Thermal comfort - Overheating	PHPP, 0.75 (BRegs/PAS2035) or local standards	AECB, EnerPhit, RIBA 2030 Climate Challenge			x
	Temperature in living, dining, kitchen and bathroom	21 degrees	ESUK	x		
	Temperature in bedrooms (each Property)	18 degrees	ESUK	x		
	Control (each Property)	The heating time and temperature control and the override or 'boost' function all work correctly.	ESUK			x
	Summer overheating	Less than 11 summer days a year are over a comfort temperature of 26°C in all monitored rooms	ESUK	x		
	Minimum Operating Temperature (degC)	Winter - 18 to 21	UK Gov Regs	x		
	Max Operating Temperature (degC)	Summer - 25 to 28 degrees	CIBSE	x		
	Min Thermal Conductivity (W/m ² K)	Roofs: 0.16 W/m ² K, Walls: 0.30 W/m ² K, Floors: 0.25 W/m ² K	UK Building Regs - EWI Pro		x	
	Max Thermal Conductivity (W/m ² K)	TBC	UK Building Regs - EWI Pro		x	
Air quality	Airtightness (m ³ /h/m ² at 50Pa)	≤1 to ≤5	LETI Retrofit, AECB, EnerPhit	x		
	Surface condensation	PHPP, 0.75 (BRegs/PAS2035) or local standards	Building Regs, PAS2035			x

Transform-ER hypothesis specification

Category	Performance Requirement	Hypothesis Specification	Source	Level 1	Level 2	Level 3
Air Quality	Ventilation (m ³ /h.person)	30	LETI Retrofit, AECB, EnerPHit, EnerPHit, Building Regs - Part F. Retrofit Standard e.g. Passivhaus EnerPHit	x		
	Max air velocity (drafts) (each Property)	<0.2m/s while heating is active where people can reasonably be expected to sit or sleep.	ESUK		x	
	Ventilation Requirements		Building Regs - Part F. Retrofit Standard e.g. Passivhaus EnerPHit		x	
	Filtration Grade		Building Regs - Part F. Retrofit Standard e.g. Passivhaus EnerPHit		x	
	Room Pressure Requirement (pa)		Building Regs - Part F. Retrofit Standard e.g. Passivhaus EnerPHit		x	
	Supply/Extract		Building Regs - Part F. Retrofit Standard e.g. Passivhaus EnerPHit		x	
	Permeability (m ³ @50Pa)		Building Regs - Part F. Retrofit Standard e.g. Passivhaus EnerPHit		x	
Visual	Internal noise from ES services (each property)	30 dBA absolute limit in living rooms/ bedrooms or where background noise is higher use relative limit of <2 dBA.	ESUK		x	
	Noise attenuation from outside and neighbours (each property)	Noise attenuation from outside and between dwellings remains the same or greater than prior to carrying out the noise works.	ESUK		x	
	Sound insulation (dB)	43 to 64	Building Regs - Part E	x		

Transform-ER hypothesis specification

Category	Performance Requirement	Hypothesis Specification	Source	Level 1	Level 2	Level 3
Vibration	Minimum floor natural frequency (Hz)	8	Eurocode/ British Standard			x
	Response factor					x
Functional	Drainage locations		UK Buildings Regs - Part H			x
	Static loading (kPa/kN)	1.5 to 5 uniformity distributed load kN/m ² , depending on specific room	British Standards - BS 6399			x
	Water inlet locations		UK Building Regs - Part G			x
	Gas/oil supply locations		UK Building Regs - Part J			x
	Power supply locations		UK Building Regs - Part P			x
	Comms locations		UK Building Regs - Part R			x
Fire	Min fire resistance (mins)	Min 30 to 90 minutes depending on volume	UK Building Regs - Part B	x		
	Min resistance to fire (rating)	Client specified	UK Building Regs - Part B		x	
	Fire detection		UK Building Regs - Part B	x		
Robustness	Robustness		TBC - in context of retrofit measures being stolen during/after installation		x	
	Design life	40 years	ESUK	x		
Security	Access		TBC-in context of retrofit measures being stolen during/after installation			x
	Access control		TBC-in context of retrofit measures being stolen during/after installation			x

Transform-ER hypothesis specification

Category	Performance Requirement	Hypothesis Specification	Source	Level 1	Level 2	Level 3
Security	Security systems		TBC-in context of retrofit measures being stolen during/after installation			x
Geometry	Max occupancy		Archetype/portfolio specified		x	
	Minimum height (m)		Archetype/portfolio specified		x	
	Maximum height (m)		Archetype/portfolio specified		x	
	Minimum roof space void (m)		Archetype/portfolio specified		x	
	Maximum roof space void (m)		Archetype/portfolio specified		x	
	Minimum area (m ²)		Archetype/portfolio specified		x	
	Maximum area (m ²)		Archetype/portfolio specified		x	
Sustainability	Percentage of recyclable material		TBC			x
	Embodied carbon of retrofit materials		TBC			x
	Design for disassembly/deconstruction		TBC			x
	Acceptable moisture levels in the building		TBC			x
	Minimum lifespan of the materials used in the building		TBC			x
	Methods of disposal used during construction phase		TBC			x
	Right to repair		TBC			x
Local water supply not contaminated during construction		TBC			x	

Step 5 - Conclusions, recommendations and next steps

Step 5 considers:

- **Conclusions** – from analysing the housing stock of the UK.
- **Recommendations** – the medium-to long-term recommendations to reach retrofit at scale.
- **Next steps** – the short-term Transform-ER goals.

Conclusions

The findings within this report show that, to meet net zero 2050 targets set out in UK legislation and reduce the emissions of the UK's housing stock, a step change is required in how we approach retrofit to accelerate the retrofitting rate (RR). As has been found in the Transforming Construction Challenge for new build government pipeline, a move towards a platform approach to gain benefits of Manufacturing-Led retrofit should be adopted. This enables mass customisation through developing interoperable kits-of-parts.

The Transform-ER consortium believes a move towards a Manufacturing-Led approach can ramp up the delivery of retrofit at scale, through proving the Transform-ER delivery model.

A growing number of organisations have published reports highlighting the need to decarbonise the UK housing stock through achieving retrofit at scale. The UK now needs to shift from knowing and reporting about the problem into actions to tackle the problem, through rapidly establishing delivery models and accelerating the deployment of retrofits at a large portfolio level.

Through use of the housing surveys of the nations of the UK, the housing stock data can be used to sort by tenure, dwelling form, EPC rating and other sorting methods to build a greater understanding of the retrofit pipeline, at a national level.

Limitations of this data have been identified, from EPC accuracy to unknowns on the characterisation of insulation, and a further need for granularity of data for manufacturers, architects and other stakeholders involved in retrofitting. Accurate data for the housing stock of the UK is required to fully understand the pipeline of archetypes. Use of technology may need to be adopted to increase the reliability of data capture on survey information.

Retrofit delivery to date has been financed by a number of different government funding schemes, all with different aims and outcomes, most of which have not set whole-house retrofit as the strategic target, often with piecemeal measures installed i.e. a shallow retrofit. There is still vast potential to decarbonise the remaining housing stock, if the right business and finance models are adopted at a national level, and the annual retrofitting rate is accelerated through development of the UK supply chain capability and capacity, to deliver one million retrofits per annum.



There is still vast potential to decarbonise the remaining housing stock by adopting the right business and finance model and development of the supply chain

Recommendations

Initiating a standardised UK approach to retrofit. By consolidating pockets of pilot and small scale retrofit projects into portfolios of properties. In line with the growing number of organisations outlining the need for retrofit at scale, such as the [National Retrofit Hub](#), the [Sustainable Development Foundation](#) and the [Institution of Engineering and Technology](#), address the barriers to retrofit through:

DEMAND - aggregation of retrofit pipeline.

- Quantification of the retrofit demand to clearly define a pipeline of potential work, minimising effort by using an archetype approach.
- Archetype definition: To help identify pipelines of properties with common energy performance characteristics.



- Unlocking finance
- Consistent government policy
- Developing UK supply chain capability and capacity
- Addressing the national skills and workforce shortage
- Increasing user uptake and demand
- Developing new delivery models
- Driving innovation of retrofit products and solutions.

Streamlining retrofit. By adopting the Demand – Develop – Deploy structure recommended by the CIH product platform rulebook, the overall process of retrofit can be streamlined, as will be developed further in the Transform-ER project’s next phases and written up in the Retrofit Rulebook.

Several key opportunities exist for streamlining retrofit, categorised into Demand, Develop, and Deploy:

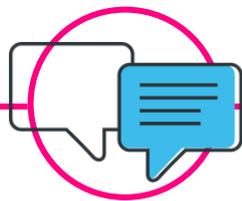
An archetype in this report refers to the typical example of a property subject to energy rehabilitation measures. The archetype is defined by a series of characteristics. All homes that share these characteristics can, by extension, be added to the pipeline and be subject to renovation with known expected outcomes.

The more characteristics defined, the greater the definition of the archetype, leading to greater similarity with the homes added to the archetype but a smaller number of such homes. An archetype should consider as a minimum ‘dwelling type’ and ‘age’. ‘Archetype definition’ may be one of the first steps in the DEMAND phase of the Retrofit Rulebook.

- Aggregating portfolios of properties using digital tools, such as:
 - Digital platform
 - Product database
 - Portfolios and properties database
 - Digital condition surveys.
- Harmonise, Rationalise, and Digitise technical retrofit requirements.

DEVELOP - design standardised retrofit products and kits-of-parts.

- Product specification and development of product databases, in line with UK standards, to support the ramp up of product development and ensure structured product information.
 - 'Design for X' toolsets to develop products, e.g. U-value calculators to optimise products for thermal performance.
 - An expediated route to certification, enabling manufacturers/designers to innovate and follow best practice engineering principles for retrofit.
- Fostering greater collaboration between manufacturers and designers to develop standardised kits-of-parts.
 - Develop rules and principles to enable standardisation for retrofit.
 - A standardised approach to interfaces.
 - Improve UK capability for Manufacturing-Led retrofit.
 - Improve site delivery logistics and processes to deliver retrofit projects efficiently and to quality.
 - Identify skills and competency gaps and opportunities for existing construction workforce to upskill into future retrofit specialists.



Fostering greater collaboration between manufacturers and designers to develop standardised kits-of-parts.

DEPLOY - defining processes to commercialise products and repeatedly install retrofits effectively.

- Financing model - expand the range of financial options to move away from purely grant focused schemes and bring in external finance.
- Contracting and procurement - more collaborative contracting and procurement aiming to form alliances between suppliers and customers to:
 - Ensure a shared vision
 - Produce mutually beneficial outcomes
 - Mitigate risks through transparent planning
 - Identify further opportunities
 - React together to future market changes through mutual innovation.
- Bridge the skills gap and limited labour force to support onsite installation through:
 - Standardising the process to simplify skill sets required, to build individual competency and UK manufacturing capability. examples include:
 - Application of Design for Manufacture and Assembly (DfMA) principles
 - Error proofing of complex operations.
 - Standardising and simplifying the skill sets for a future multi-skilled offsite and onsite workforce.
- Define the retrofit strategy and the retrofitting target using feedback data, for example:
 - Use of sensors to gather data to inform energy targets
 - Energy modelling using data from sensors, to identify achievable outcomes.



More collaborative contracting and procurement aiming to form alliances between suppliers and customers to ensure a share vision and produce mutually beneficial outcomes.

Next steps

The Transform-ER consortium have identified the following steps as key to achieving national retrofit at scale:

Develop retrofit kits-of-parts

Manufacturer led design and development of retrofit products and kits-of-parts, optimised for offsite construction and ease of onsite deployment.

Author the Retrofit Rulebook

The Retrofit Rulebook has two core aims:

1. Define an approach for developing interoperability rules and standards for retrofit products and systems for industry to follow. Provide practical examples of interoperability rules and standards from the Transform-ER project, that will be written up as case studies, for a set number of interfaces, archetypes, and products and systems from the consortium's industrial partners.
2. Apply the Demand - Develop - Deploy structure from the Construction Innovation Hub (CIH, 2022) to define guidance on delivering retrofit at scale, using the knowledge and lessons learned during the project. This shall capture key insights gained from the expertise within the consortium's partners, through overcoming core barriers of reaching retrofit at scale, and writing this into the Retrofit Rulebook, for the benefit of wider industry.

Develop the Transform-ER digital platform

To streamline the aggregation of demand for retrofit across the UK, assess portfolios of properties, provide solution matching of products and solutions to different archetypes. The Digital Platform shall streamline the early stages of the retrofit process in line with PAS 2030 and PAS 2035 and provide a product database for standardised retrofit kits-of-parts.

Develop new routes to certification and testing

To fast-track the process of approving retrofit products and systems, ensuring they meet a level of quality and performance standards, aiming to aid the ramp up of approved and quality assured retrofit products available on the market. This aims to meet the clear market need in developing an expediated product development pathway through which products and systems can be tested and certified to ensure safe and high-quality retrofit products enter the market.

Develop the Transform-ER retrofit delivery vehicle

Development and launch of the operational model for Transform-ER, to begin deploying retrofits at scale. A wide range of stakeholders is required to finance, develop, aggregate demand, and install products and systems to upgrade and decarbonise the UK housing stock. Design of the contracting and delivery model is a fundamental step in transforming the industry towards repeatability and economies of scale.

Calls to action

Transform-ER has a far-reaching spectrum of stakeholders invested in its success. The following key stakeholders have been identified (as shown in [Figure 1](#)) as critical to achieving our mission, with clear calls to action for each:

We need a future owner of the Retrofit Rulebook

As we move beyond the R&D phase, we need an owner of the Retrofit Rulebook to update the guidance as the Transform-ER delivery model ramps up delivery of retrofit at scale.

The Retrofit Rulebook will set out clear guidance for industry organisations wishing to adopt the Transform-ER approach and deliver high-performance, cost-effective home energy upgrades at scale.

This will likely be, at least in part, managed by the new retrofit delivery vehicle but support from other industry bodies would be beneficial. [Get in touch](#) if you are interested in supporting this work.

We need clients to sign up to the new retrofit delivery vehicle

Define the Need helps clarify what a manufacturing / platform approach is for achieving retrofit at scale, and the benefits of this in working with a new delivery model such as Transform-ER. Transform-ER's retrofit delivery vehicle will be launched in 2025 - [sign up for updates](#).

We need new entrants to the retrofit market

From manufacturers and installers to retrofit assessors and architects, we need new organisations to join the retrofit revolution.

Define the Need illustrates the size of the retrofit challenge, why transformation is required, how transformation can be achieved through a Manufacturing-Led approach and delivery model designed for scale, and insights into some of the market potential.

Our work on streamlining accreditation and certification pathways is designed to support you in this journey - [sign up for updates](#).

We need support from relevant government departments with a long-term strategy and funding support

Define the Need demonstrates how retrofit at scale can be delivered by new delivery models such as Transform-ER as part of a procurement framework, and why this is so essential to the health and environmental wellbeing of the country. [Read our 5 key points for policymakers](#).

Appendix A

The Value Toolkit

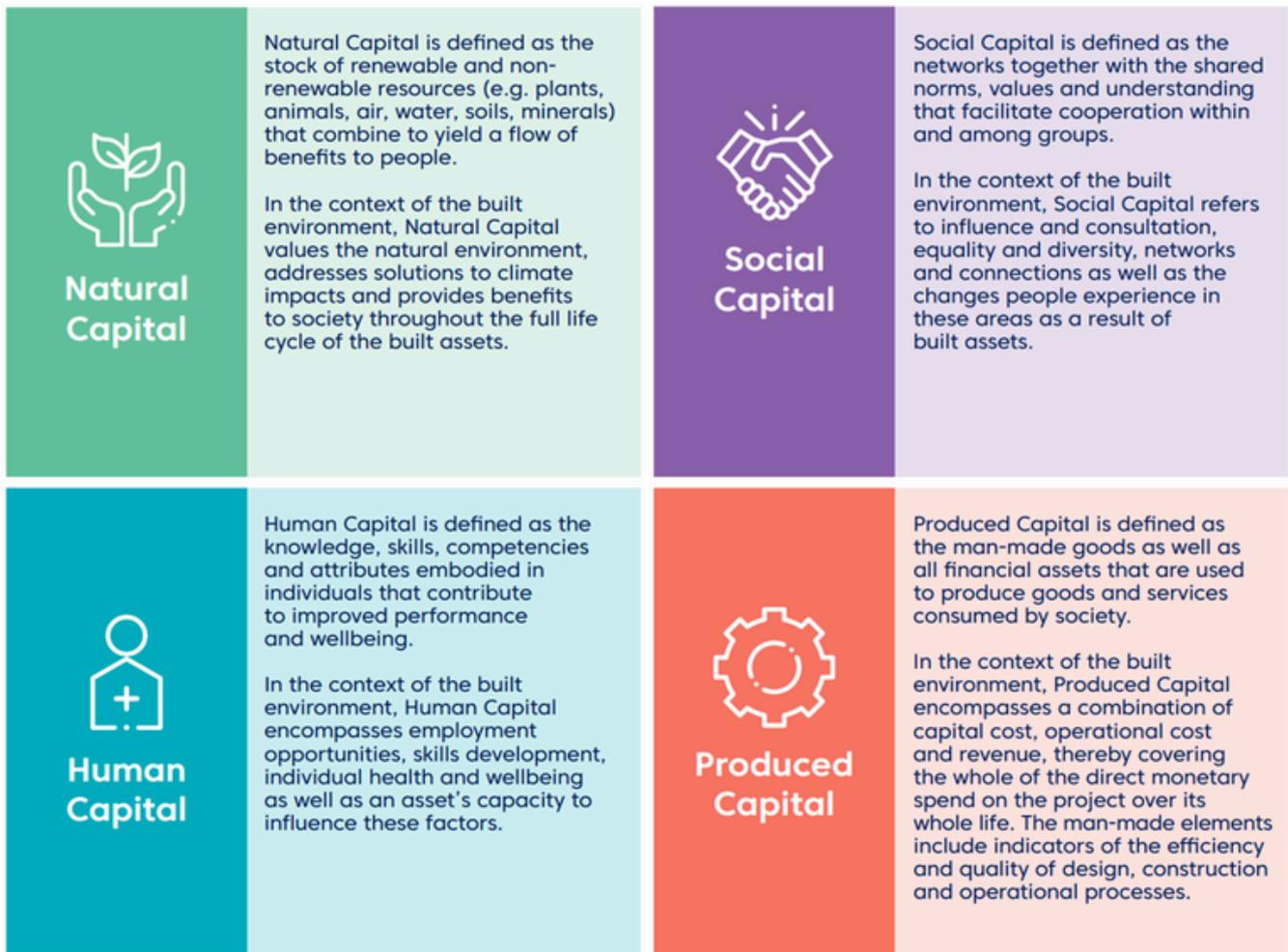


Figure 33: Four Capital approach definitions (CIH, 2022).

As well as quantifying the scale of retrofit demand, it is important in deploying retrofit at scale to consider the strategic value.

As such, considering use of Construction Innovation Hub's [Value Toolkit](#), a more holistic analysis can be made to consider natural, human, produced and social capital. Some examples of considering the four capitals of the value toolkit for retrofit are given below.

Natural Capital

- Reduced carbon emissions, 25% of UK emissions can be attributed to the BE sector (UKGBC, 2021).
- Improved air quality, gas combustion accounts for 38% of NO_x emissions in Central London (Howard, 2016).

Human Capital

- Enhanced health and wellbeing - UK experiences an estimated 10,000 deaths a year attributed to cold homes (Seaton-O'Connor, et al., 2024) and a further 2,000 due to overheating in homes (HM Government, 2017), costing £1.4 billion per year to the NHS (BRE, 2023).
- Up to 75% of the benefits of retrofit can be related to improved health of the occupants (International Energy Agency, 2014).
- Skills development, 500,000 high skilled jobs across the country (UKGBC, 2024).

Social Capital

- Reduction in energy poverty, pilot studies in Milan showed a reduction in energy poverty by 3.5% (C40, 2020).
- Community resilience, by retrofitting low cost and social housing, community resilience can be built on a reduced dependency on fluctuating energy costs.

Produced Capital

- Lower operational costs, the Milan pilot study demonstrated a 53% reduction in energy costs (C40, 2020).
- Increased property value, improving energy efficiency from an EPC G to A can increase property value by 14% (Money Super Market, 2022).

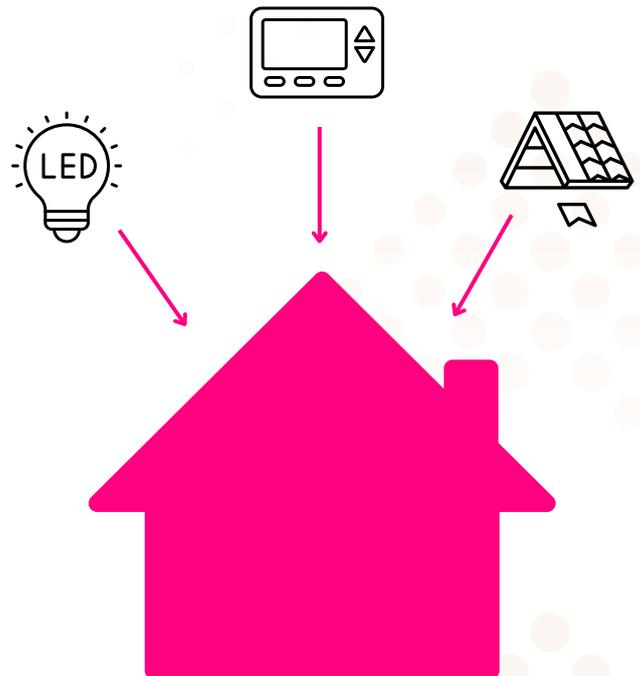
Appendix B

Retrofit approaches by strategy

When it comes to retrofitting, different but similar strategies exist (Institute for Sustainability and UCL-Energy, 2012; NBS, 2023). These vary in extent, planning style, and overall approach.

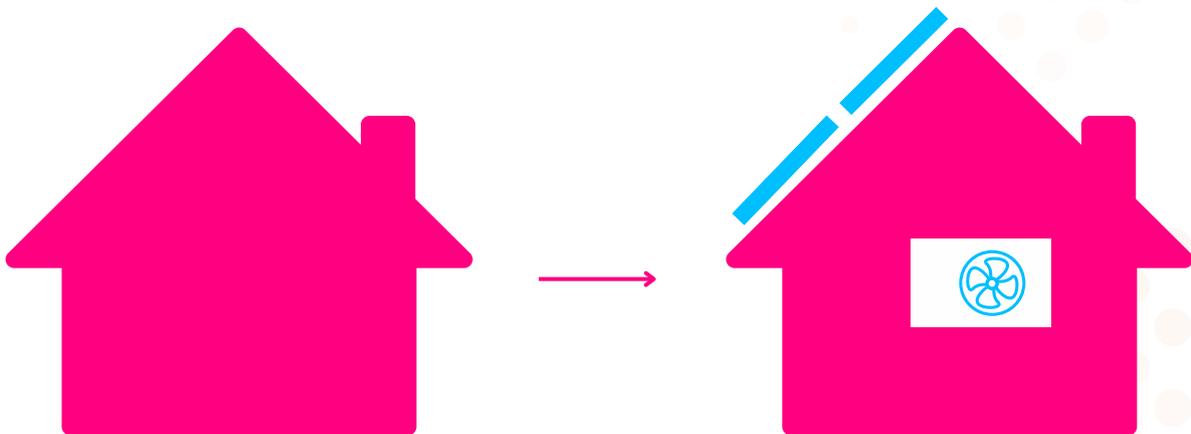
1. Shallow retrofit

- **Focus:** Aims to improve energy efficiency and comfort with minimal disruption and cost, focusing on easy, low-cost upgrades.
 - **Key principle:** Targets quick fixes that provide immediate, though limited, improvements in energy efficiency.
 - **Typical measures:**
 - Replacing lighting with LED bulbs
 - Adding weather stripping
 - Installing programmable thermostats
 - Minor insulation improvements (e.g. loft insulation).
 - **Level of disruption:** Low - involves minimal disruption as it focuses on simple, non-invasive upgrades.
 - **Costs:** Low - relatively inexpensive, with investments typically in the range of hundreds to a few thousand pounds.
 - **Carbon and energy savings:** Low - energy savings usually range from 5% to 15%, with modest reductions in carbon emissions.
- **Applicable properties:** Homeowners or building managers seeking immediate, low-cost improvements without major renovations.
 - **Planning:** Requires little or no planning.
 - **Overall approach:** Traditional retrofit with little opportunity to implement Transform-ER approach.



2. Fabric first approach

- **Focus:** Prioritises enhancing the building's fabric (walls, roof, floors, doors, windows) before addressing mechanical systems.
- **Key principle:** Optimising the building envelope reduces energy consumption, allowing mechanical systems to be smaller and more efficient.
- **Typical measures:**
 - High-quality insulation
 - Energy-efficient windows and doors
 - Airtightness improvements
 - Reducing thermal bridging
 - Smaller heating and energy systems.
- **Level of disruption:** Moderate - may require significant construction work, such as installing insulation or replacing windows, but typically less disruptive than deep retrofits that involve mechanical system overhauls.
- **Costs:** Moderate to high - costs vary based on the extent of fabric improvements, but typically more affordable than deep retrofits. With fabric improvements, running costs of smart energy systems will be lower.
- **Carbon and energy savings:** Moderate to high - energy savings can range from 20% to 40%, with corresponding reductions in carbon emissions. Low/no carbon energy systems will further reduce this.
- **Applicable properties:** Both new builds and retrofits (residential and commercial), particularly where long-term energy efficiency is a priority.
- **Planning:** This can be implemented as a step-by-step (phased) or fully planned retrofit, with improving the fabric of the property making up the first phase of the work.
- **Overall approach:** This approach is compatible with either traditional or Transform-ER approaches.



3. Whole-house retrofit/deep retrofit

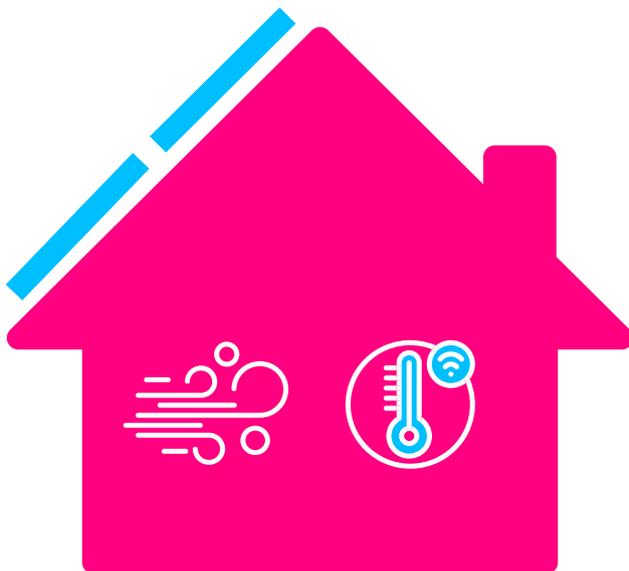
- **Focus:** A deep and holistic upgrade to the entire home, improving energy efficiency, comfort, health, and resilience (e.g. homes exposed to severe weather conditions). It entails a comprehensive plan that considers all aspects of the building such as air quality, ventilation, occupants' activity and use of the house.
- **Scope:** Includes energy efficiency upgrades, indoor air quality improvements, water usage optimisation, and occupant comfort enhancements, treating the home as a system.
- **Typical measures:**
 - Comprehensive fabric upgrades
 - High-efficiency heating, cooling, and ventilation
 - Water efficiency and air quality improvements
 - Smart home technologies.
- **Level of disruption:** High - similar to a deep retrofit, it can be highly disruptive, potentially requiring temporary relocation of occupants.
- **Costs:** High - comparable to deep retrofits, often involving significant investment in the tens of thousands to hundreds of thousands of pounds.
- **Carbon and energy savings:** High - energy savings typically range from 50% to 80%, with significant reductions in carbon emissions and improvements in overall home performance.
- **Applicable properties:** Primarily residential, especially for homeowners looking to improve energy efficiency and the overall living environment comprehensively.
- **Planning:** This strategy requires deeper planning in order to fully integrate all the systems that make up a deep retrofit.
- **Overall approach:** This strategy is ideal for the Transform-ER approach.



4. Smart energy systems approach

- **Focus:** Prioritises decarbonising the energy systems within a property by relying on electrical systems powered with renewable energy.
- **Scope:** This involves minimal fabric improvements, renewable energy, battery storage, smart tariffs and electrified heat.
- **Typical measures:**
 - Heat pumps
 - Solar PV
 - Smart home technologies
 - Battery storage
 - Smart tariffs.
- **Level of disruption:** High – occupants may need to relocate during work, with upgrades to both energy and heating systems.
- **Costs:** High – energy and heating systems require both modification to the building and high material costs, which makes it expensive. It will take longer to recoup the costs due to the remaining inefficiency of the building.

- **Carbon and energy savings:** Energy usage will remain high as there is no effort to improve the efficiency of the building. However, carbon emissions should be reduced through cleaner energy sources for heating and microgeneration through solar PV.
- **Applicable properties:** Properties that are already at a reasonable level of thermal performance.
- **Planning:** Little or no planning required to integrate systems in most cases. Exclusions could be the requirement for 3 phase power for high power heat pumps.
- **Overall approach:** Similarly to shallow retrofits, individual energy system upgrades are likely to require a traditional approach. However, if integrating them with other measures, could provide scope for utilising the Transform-ER approach.



Appendix C

Retrofit energy targets

	LETI Retrofit			AECB			Passivhaus EnerPhit	RIBA 2030 Climate Challenge	
	Best practice Constrained	Best practice Unconstrained	Exemplar	CarbonLite Step-by-step	CarbonLite retrofit	Silver		2025 targets	2030 targets
Fossil fuel	Free	Free	Free	Free	Free [1]	Free	Free	Reduce	Free
Emissions kg. CO2/m ² /yr	-	-	-	-	-	22	-		
Primary Energy Renewable	-	-	-	-	-	-	≤135+(QH - 15)	≤ 60	≤ 35
Primary Energy EUI (kWh/m ² /yr)	≤ 60	≤ 50	≤ 40	-	-	≤ 120	≤ 120		
Space Heat Demand (kWh/m ² /yr)	≤ 60	≤ 50	≤ 25	-	≤ 50[2]	≤ 40	≤ 20 / 25 / 30[4]		≤ 25 recognises challenges of existing buildings.
Space cooling demand (kWh/m ² /yr)	-	-	-	-	≤15	-	≤ 15 /25		≤ 20, focus on passive cooling techniques.
Hot Water demand	20-25	20-25	20-25	-	-	-	-		
Renewable energy (PVP, % roof area)	>0	>40	>40	-	Not required	-	-		
Airtightness (m ³ /h/m ² at 50Pa)	≤ 3	≤ 1.5	≤ 1	≤ 5	≤ 2	-	≤ 1		
Thermal bridges (W/(m ² K))	-	-	-	-	≤ 0.01	-	ψ ≤ 0.01 or χ ≤ 0.04		
Thermal comfort - Overheating	-	-	-	-	Max 10% at > 25°C	-	Max 10% > 25°C	25-28°C max. for 1%occupied hours	
Surface condensation	-	-	-	-	-	-	PHPP, 0.75 (BRegs/PAS 2035) or local standards		
Ventilation (m ³ /h.person)	-	[4]	-	-	[5]	-	30		
Methodology	PHPP	PHPP	PHPP	-	PHPP	PHPP	PHPP		

[1] Existing systems may be retained, but a practical plan to allow for future low carbon heating supply must be in place. [2] ≤ 100 kWh/m²/yr with certifier approved exemption. [3] Or circa 20-60 for component approach. [4] Depending on climate zone. [5] MVHR specified. Rate not specified. [6] Continuous MEV or MVHR specified. PAS 2035 Annex C or Part F of Building Regulations. EUI = Energy use intensity. PVP = photovoltaic panels. QH = achieved space heating demand. ψ = Nonlinear thermal bridges. χ = Punctiform thermal bridges

Appendix D

Key insights from Transform-ER to date

Archetype definition

Archetype definition may be one of the key stages in the DEMAND phase of the Retrofit Rulebook. This enables accurate definition of the pipeline. The importance of archetype definition has also been identified by organisations such as the National Retrofit Hub.

Interfaces

- The Transform-ER industrial partners have identified 140 interfaces that could have potential for standard details, and rules governing a standardised approach for retrofit product development and kits-of-parts.
- The Transform-ER consortium has identified 10 priority interfaces to work through. The lessons learned shall form the case study examples in the Retrofit Rulebook.

Interoperability Rules / Standards

Transform-ER has developed a methodology to work through each of the interfaces, as follows:



Transform-ER 'proposed programmes'

The following priority programmes have been identified for the consortium partners as the initial focus:

1. 1920s - 1940s solid brick council estate houses
2. BISF (British Iron & Steel Federation) houses
3. Wimpey No Fines houses
4. 1920s - 1970s cavity wall houses.

Appendix E

5 key points for policymakers

1. It's critical that we tackle the UK's big retrofit challenge

We must dramatically increase our retrofitting rate to meet the Government's net zero targets - it is currently 6% of what is needed. This will also help address our housing stock's critical state, characterised by poor energy efficiency and unacceptable living conditions.

2. There's a huge market opportunity

Roughly 50% of the UK's housing is still rated at Band D or lower. The Manufacturing Technology Centre (the MTC) estimates that retrofitting these homes represents an estimated market potential of between £20bn and £60bn annually for the UK economy.

3. We need systemic change for systemic barriers

Transform-ER is taking a systemic approach to tackle retrofit's barriers to scale - including high costs and funding gaps, an underdeveloped supply chain, workforce and skills shortages, lack of industry standardisation and absence of proven delivery models including financing.

4. We can unlock better retrofit for everyone

Transform-ER is developing a new retrofit delivery model for financeable, high-quality and cost-effective solutions and a radically new resident engagement programme:

- The industry benefits from a standardised end-to-end process with improved procurement and contracting processes.
- Residents benefit from increased agency and desirable, comfortable homes with guaranteed performance where damp, mould and overheating risks are mitigated.

5. Adopting a Manufacturing-Led approach is essential

The consortium advises that a Manufacturing-Led approach to industrialise the retrofit sector can facilitate large-scale implementation through increased productivity and efficiency. This includes aggregating demand and applying technology to develop standardised kits-of-parts to enable common solutions to be applied to different archetypes.



Definitions

- **Retrofit** - Retrofitting is the process of making improvements to your home for a beneficial outcome, for example, to increase energy efficiency with lower emissions.
- **Category 1 hazards** - It is the type of hazard classified as serious by the housing health and safety rating system (HHSRS). The HHSRS is a risk-based evaluation tool to help local authorities identify and protect against potential risks and hazards to health and safety from any deficiencies identified in dwellings.
- **Compatibility** - The ability of two or more components within a system to exist within the same system without interference.
- **Hard-to-treat** - It is the adjective given to uninsulated properties that are more difficult or expensive to insulate due to their specific conditions or nature. This can refer to walls or lofts. This adjective is opposed to 'easy-to-treat'.
- **Interoperability** - The ability of different components within a system to seamlessly work together, communicate, and exchange data effectively without the need for additional work.
- **Kit-of-parts** - A collection of repeatable, standardised building components that are pre-engineered and designed to create a variety of assemblies which define part or all of a finished building (CIH, 2022).
- **Mass customisation** - a manufacturing paradigm that enables customised and personalised design at a cost near mass production (Larsen Maria Stoettrup Schioenning, 2019).
- **Platform approach** - Maximising the use of the same components across different types of infrastructure, designed by industry to have as wide a use as possible (CIH, 2021).
- **Rule** - An accepted principle or instruction that states the way things are or should be done and tells you what you are allowed or not allowed to do. (Cambridge Dictionary, 2024).
- **Standard** - A level of quality (Cambridge Dictionary, 2024).
- **Systems thinking** - Systems thinking in the context of decarbonising within the built environment is a holistic approach that acknowledges the interconnectedness and complexity of various components within the built environment. It is crucial for achieving net zero carbon goals, as it allows stakeholders to understand how different elements—such as individual assets, networks, and broader systems—interact and influence one another.
- **Distributed generation** - Electricity generation that occurs close to the point of use, often at individual homes or businesses.
- **Centralised generation** - Large-scale power plants, like gas, coal, or nuclear power plants, that feed electricity into a national grid for wide distribution.
- **Golden thread** - The golden thread needs to be created before building work starts and the information must be kept updated throughout the design and construction process (Gov, UK, 2024).

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Define the Need

TRANSFORM-ER

Written by the MTC on behalf of the
Transform-ER consortium

Why we need to transform the retrofit
market and how

To view the summary Define the Need report, please visit:
<https://bit.ly/dtn-summary>

To find out more about the Transform-ER project and keep up-to-date with
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