BAILY GARNER

Retrofitting existing homes

A Practical Toolkit Towards Net Zero

Revision A (June 2022)

CONTENTS

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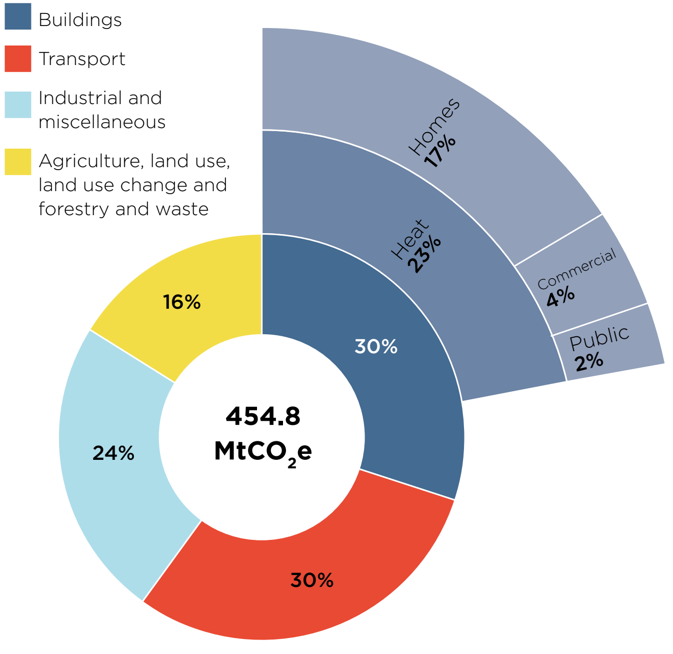
Significant revisions made since the first version of this document are written in italics.

INTRODUCTION

The UK is required to achieve net zero by 2050 and a 78% reduction by 2035 in line with the Climate Change Act 2008 and subsequent revisions in 2019 and 2021.

The built environment makes up 30% of the total UK **emissions**, with heating homes responsible for 17% of emissions alone.

Figure 1 – Emissions chart



UK Government Heat and Buildings Strategy October 2021

Figure 1 shows the proportion of emissions in 2019 from buildings to the nearest whole number; of the 454.8 mega tonnes of carbon dioxide equivalent (MtCO2e) total emissions, 23% were due to heating buildings, with the largest proportion of this stemming from homes.

Baily Garner is a multidisciplinary consultancy with over 45 years of experience of working on existing social homes and award-winning energy efficiency retrofits.

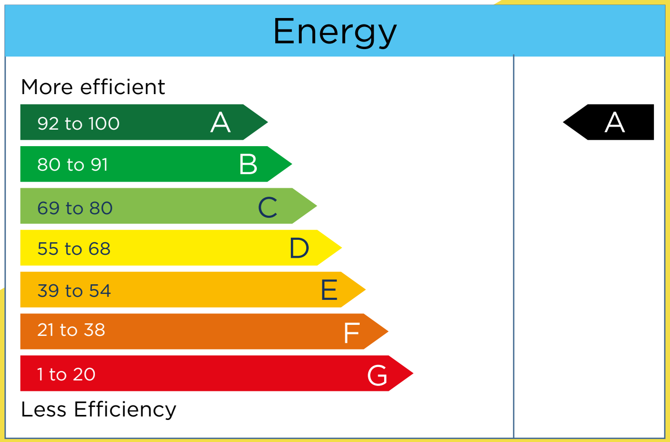
We have produced this toolkit revision as a pragmatic guide to help build organisations' understanding of the key issues and to set out and navigate a path towards net zero retrofit that suits the needs and priorities of your business. It lays out the challenges, the policy context and the choices facing organisations retrofitting their existing homes. *This second version has added multi-residential flat archetypes and provided updated capital costs and added whole life costs.*

Many organisations will have new build programmes that will need to achieve net zero carbon homes as envisaged by the government's **Future Homes Standard.** This is the subject of our other toolkit: The Future Homes Standard a Practical Toolkit Towards Net Zero which can be found **here**.

This toolkit takes existing homes, which represent some of the most common social housing stock archetypes, and identifies energy efficient measures which can be implemented to improve the energy performance certificate (EPC) bandings (see **figure 2**) and reduce the heat demand of homes.

It also identifies the broad cost impacts of the options presented for your organisation and your residents and draws together other considerations such as **whole life carbon** and the **circular economy.**

Figure 2 – EPC table



The main measure the government is using to assess the energy performance of existing homes is the EPC rating. The government's **Clean Growth Strategy** identifies homes should achieve an EPC rating of C by 2035 and by 2030 for "fuel poor" households. Social landlords are setting their own organisational targets to improve the EPC ratings of their homes. The government's aspiration for as many homes as possible to reach EPC band C is tempered with the words "practical, affordable and cost effective". The government also recognises that EPCs are imperfect, as they predict the cost of running a dwelling under a fixed occupancy and pattern of demand based on what can be determined on site by a Domestic Energy Assessor, and are consulting on their reform. Energy use intensity measured in kilowatt hours per m² (kWh/m²) of treated floor area per year is considered to be a better measure to compare design versus actual performance and allow comparison between homes.

The government published its **Net Zero Strategy: Build Back Greener** and its **Heat and Buildings Strategy**, which envisages that 38% of emissions reductions between now and 2030 will come from measures to improve the thermal performance of existing homes (see **figure 3**). Whilst there is support for social housing, the funding commitments fall short of what is required and **does not constitute a 'national retrofit strategy'**. The strategy contains a 'confirmed ambition' to end the sale of gas boilers by 2035, supports heat pump deployment and signals a strategic decision on hydrogen use by 2026.

The recently published British Energy Security Strategy also appears to be a missed opportunity to reduce energy demand from existing homes concentrating on supply side rather demand reduction. Whilst recent temporary reductions in VAT for energy efficiency measures is welcome these are swallowed up but current construction inflation.

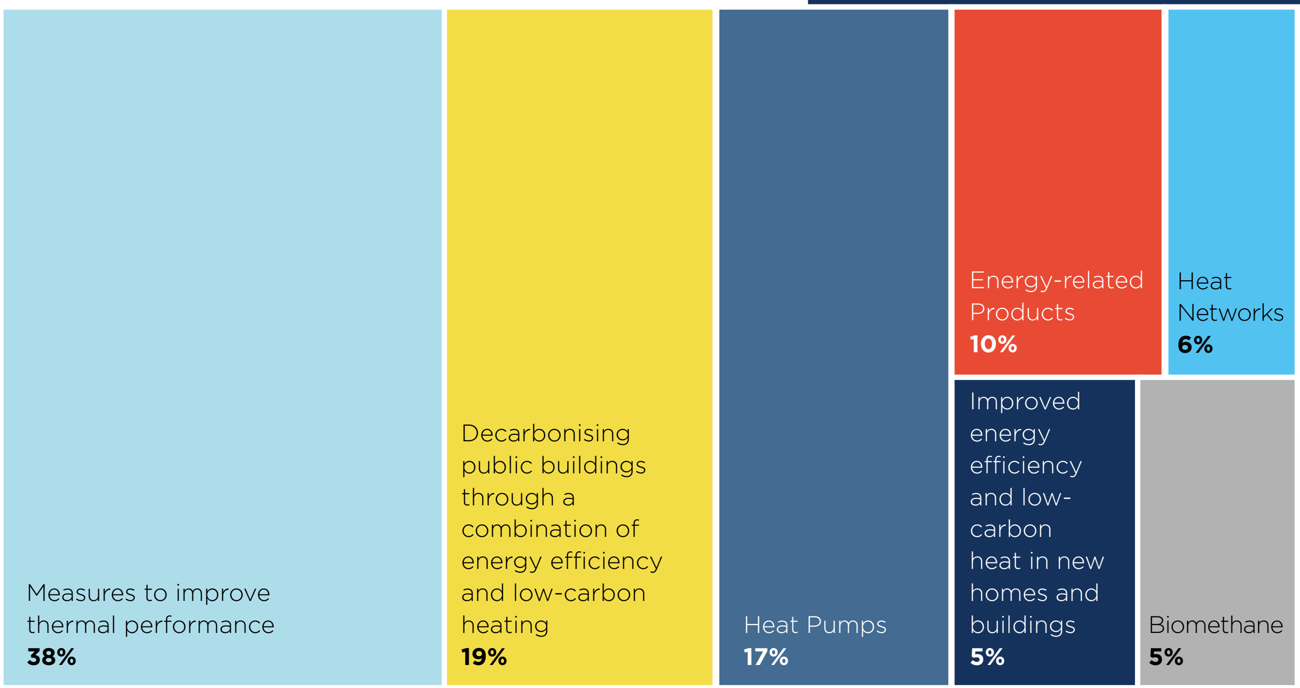
This toolkit does not comment on the adequacy or scale of the government's spending commitments but acknowledges that there is currently a funding gap. The government has a number of grant funding streams to support wider retrofit of existing stock, in particular the Social Housing Decarbonisation Fund (SHDF), which we are happy to discuss with you.

Building Regulations Parts L and F have been updated. Much of the regulations' focus is on new build, but sections covering energy efficient improvements and a risk-based approach to ventilation are expanded.

This toolkit focuses on low and mid-rise homes. High rise homes should be considered on a bespoke block-by-block basis due to their specific safety, fire and servicing characteristics. *However, new archetypes have been added which should allow landlords to consider generic options for retrofit of higher rise homes.*

Figure 3 – Breakdown of estimated potential emissions savings from heating UK buildings by 2030, by technology type

UK Government Heat and Buildings Strategy October 2021



WHAT IS RETROFIT?

A retrofit will involve the addition of insulation to building fabric and replacement of elements, components and systems to make the building more energy efficient and mitigate the impacts of climate change and biodiversity loss.

A retrofit should take a holistic approach and, to ensure good outcomes, a retrofit should take a whole building "fabric first" approach. A comprehensive retrofit of the whole building is generally known as a "deep" retrofit whereas "shallow" retrofit may upgrade certain elements allowing further improvements to be made, leading towards a net zero building, in later investment cycles. Such incremental improvements must take place within a strategic asset management plan.

The Case for Retrofit

The UK's 27 million homes constitute the oldest housing and most energy inefficient stock in Europe.[1]

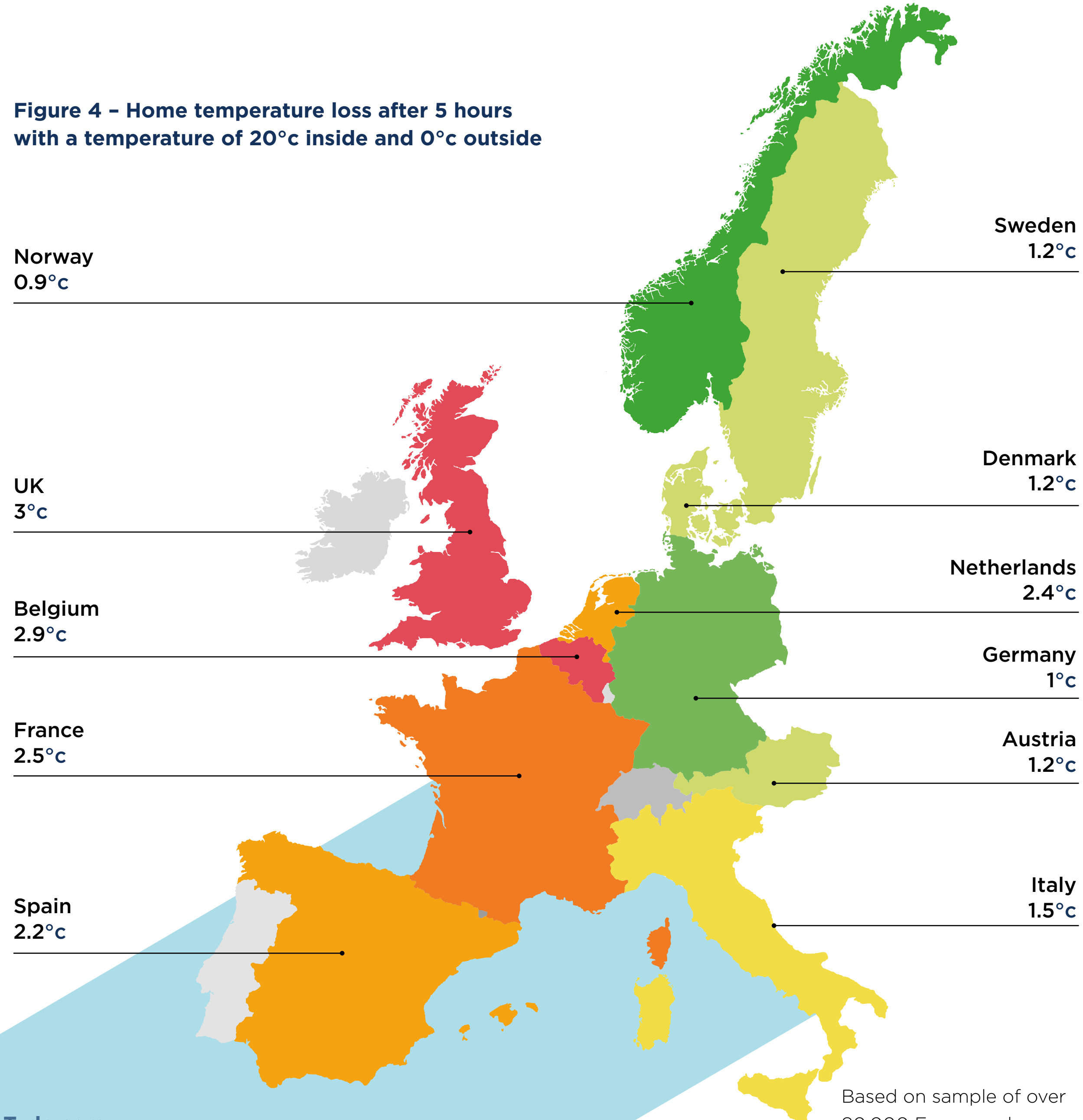
As a result, 17% of the UK's annual carbon emissions are associated with heating our domestic housing stock. It also goes without saying that increasingly many residents suffer from fuel poverty and health problems associated with underheated and damp homes.

Around 80% of the homes that will exist in 2050 have already been built and it is estimated that around 19 million properties in the UK are in the need of some energy efficiency improvements.

Social housing homes have an average SAP of 69.1 which is better than other tenures.

1. (BRE Trust: The Housing Stock of The United Kingdom Feb 2020).

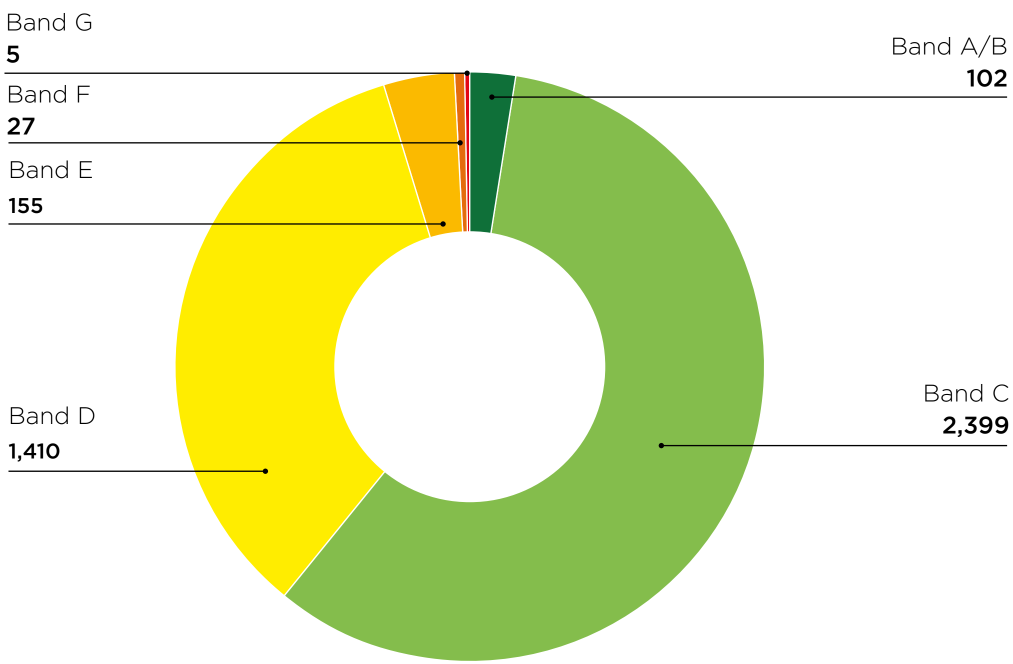
Figure 4 – Home temperature loss after 5 hours with a temperature of 20°c inside and 0°c outside



Tado.com

Based on sample of over 80,000 European homes

Figure 5 – Social Housing EPC ratings 2019 (000s)



2019-20 English Housing Survey Table AT2.8

Retrofitting is costly, with the government estimating the capital investment to get all homes to EPC Band C in the range of £35-65 billion. The independent committee on climate change estimates that a total investment of £55 billion is required to 2050. These global numbers indicate the scale of the challenge.

Our experience of deep retrofit indicates that £50,000 per social housing home is a realistic starting figure when applied at scale, but as with all averages there are large variations.

So what are the wider benefits of retrofit other than simply improving the energy efficiency of existing stock? Why is retrofitting a good idea?

Whilst this toolkit is aimed at stock holding social landlords aiming to achieve our legally binding net zero target reduction, a national retrofit programme is essential.

Reduction of energy demand from housing will also yield benefits in reducing the amount of energy infrastructure (and associated **embodied carbon**) required by the transition to a net zero economy and allow an equitable national distribution of available **renewable energy** between sectors e.g. agriculture, transport, industry etc.

Tying in with your organisation's **ESG** and **Social Value** goals, retrofitting can be seen as foundational. Retrofitting can have a positive impact on health metrics such as excess winter deaths and a reduction in **fuel poverty**. Indeed, due to the labour intensity of retrofit, retrofitting can help support a shift to a green local economy with increased opportunities for training, skills and jobs. The Construction Leadership Council's national retrofit strategy suggested the potential creation of 500,000 jobs by 2030 whilst the government estimates 240,000 low carbon jobs will be created by 2035.

THE POLICY, LEGAL AND STANDARDS FRAMEWORK

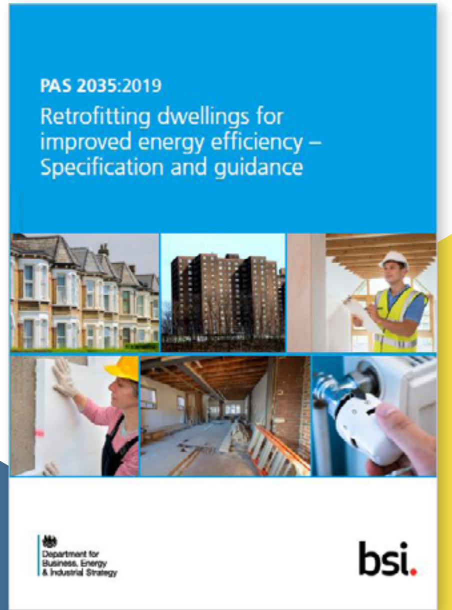
The UK has committed to achieving net zero by 2050 and the government has also committed to the Climate Change Committee's Sixth Carbon Budget reduction of 78% compared to 1990 levels by 2035. The efficiency of your organisation's stock is essentially part of this national target.

The government has published new Building Regulations Part L, Part F and Part O (overheating), which guide new build housing towards net zero carbon homes but also cover some aspects of improving and replacing energy efficiency elements, components and systems in existing stock. Many of the supporting aspects of a national retrofit strategy are in place but, as yet, there is currently no government-led national retrofit strategy. Several leading industry bodies such as The Construction Leadership Council have published a retrofit strategy and the London Energy Transformation Initiative (LETI) have published their guide to retrofit.

Retrofit is risky and in the past has sometimes resulted in unintended outcomes such as external wall insulation failures or dampness and condensation. Often a significant performance gap between the expected and actual performance of improvements has been observed.

A risk-based quality control process for retrofit (PAS2035: 2019 Retrofitted dwellings for improved energy efficiency – specification and guidance) has been adopted by the government alongside PAS 2030: 2019 Specification for the Installation of Energy Efficiency Measures in Existing Dwellings and Insulation in Residential Park Homes.

In particular, PAS2035 identifies new roles and qualifications for those involved in the retrofit to take a holistic risk-based approach.


PAS 2035:2019
Retrofitting dwellings for improved energy efficiency – Specification and guidance
Department for Business, Energy & Industrial Strategy
bsi.


Ministry of Housing, Communities & Local Government
The Future Homes Standard: 2019
Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings
Summary of responses received and Government response
January 2021
Ministry of Housing, Communities and Local Government


Ministry of Housing, Communities & Local Government
The Future Buildings Standard
Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for non-domestic buildings and dwellings; and overheating in new residential buildings
January 2021
Ministry of Housing, Communities and Local Government

Calculation and Energy Ratings

Energy performance certificates (EPCs) and the Reduced Data Standard Assessment Procedure (RdSAP) software are a broadly accepted measure of pre and post retrofit performance. *However, the government recognises that EPCs are imperfect. The Smart Meter Enabled Thermal Efficiency Ratings (SMETERS) pilot study recently concluded that smart metre bill data and sensor measurements from within occupied homes can give a more accurate measure of energy performance than an EPC.*

EPCs are required when properties are sold or first let and have a validity of ten years. A new EPC is also required following any works which would change the EPC rating. Many are generated as part of stock condition surveys and energy surveys but data is quite often cloned from similar archetypes. Data regarding EPC and SAPs can often be held on a landlord's asset systems but in some cases the quality of the data and the ability to manipulate it to inform programmes of retrofit works is limited.

Quality of data when making strategic decisions is key. Whilst RdSAP is useful in modelling potential programmes of retrofit works, the use of full SAP by a qualified assessor is necessary to achieve the granularity required in retrofit design. For many retrofit standards **Passivhaus Planning Package (PHPP)** software is required.

Retrofit Standards

It is possible to specify works which have been identified by SAP calculations whilst controlling risk and the quality of works within a PAS 2035 Framework. However, organisations may wish to drive their retrofits with reference to industry accepted standards. There a number of standards from which organisations can choose.

EnerPHit

An independent **Passivhaus** retrofit standard using PHPP modelling targeting exemplar levels of retrofit with an independent quality assurance process leading to certification.

Energiesprong

A retrofit standard targeting good levels of retrofit, using innovation to drive down cost, based upon the contract between occupier and landlord to achieve certain levels of comfort.

AECB

An independent standard for retrofit using PHPP and certified as such.

Super Homes

An independent rating scheme for retrofit based upon SAP with a star rating system.

WHAT MAKES RETROFIT SO DIFFICULT AND WHAT ARE THE KEY ISSUES?

Currently 85% of our homes rely on natural gas and 25% of our national carbon emissions arise from our gas networks. To achieve our net zero targets, current fossil fuel gas has to be replaced with low carbon alternatives. Currently, the favoured low carbon alternative is heat pumps but the government is also looking at hydrogen and industry is looking at other forms of green gas.

Currently the price multiple between gas and electricity tariff per kilowatt hour is around four times. With the efficiency of a heat pump around three times that of a gas boiler, simply installing a heat pump without improving the building fabric performance will increase fuel bills.

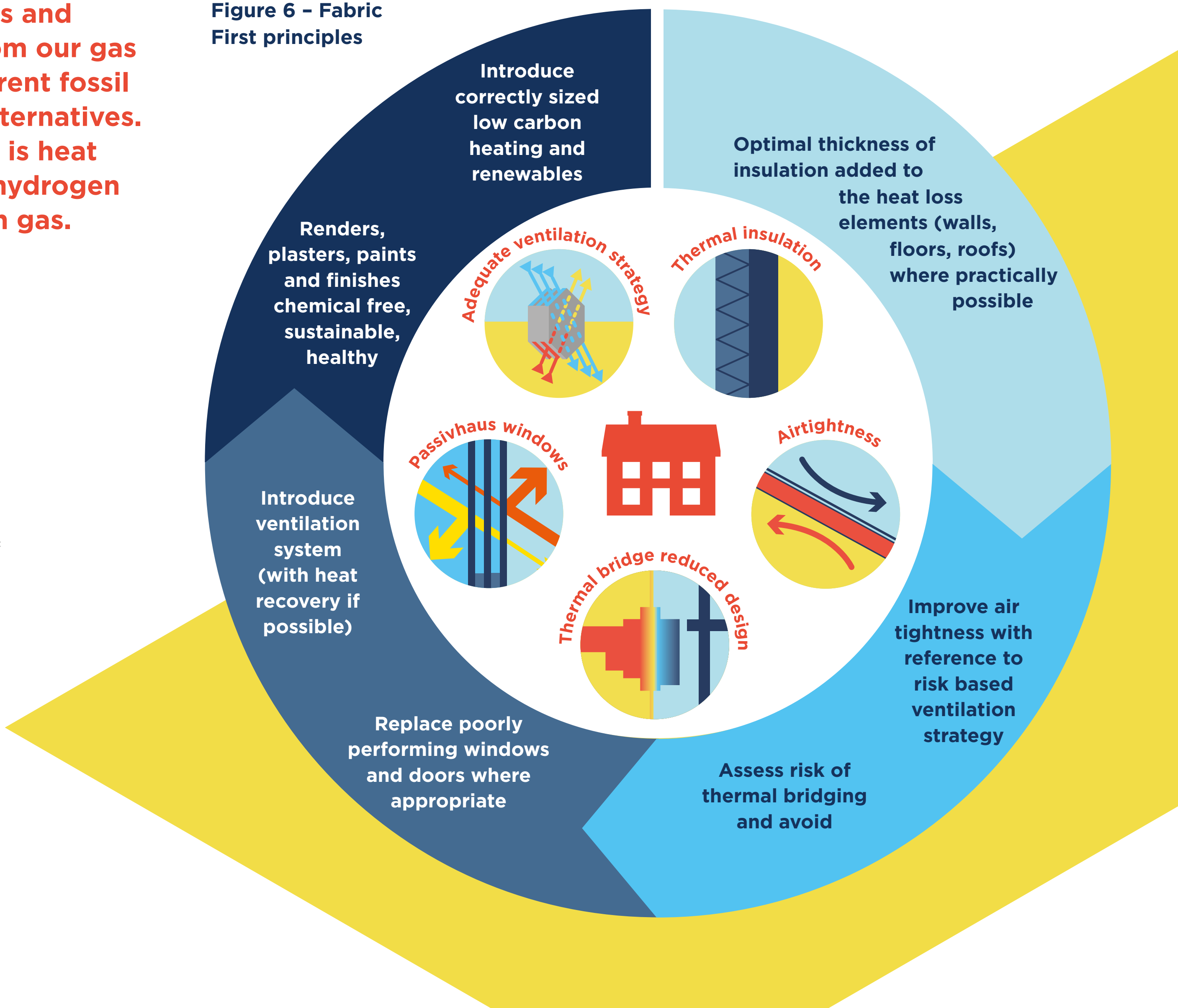
Fabric First and Lowest Regrets

Whatever the lower carbon technology deployed, an upgrade of the building's thermal envelope is required to reduce the overall energy demand. This is achieved through the addition of external or internal insulation, higher performing elements and components and improved air tightness and ventilation.

In older and period stock, the fabric first approach can present detailing and space issues externally and internally, planning issues, leaseholder and adjoining freeholder issues. This problem is particularly acute in mixed tenure terraces, semi-detached homes and flatted blocks where such detailing can add a significant cost premium.

*A fabric first approach is often framed in terms of a **'lowest regrets'** approach, meaning that the retrofit approach taken should minimise the potential of measures installed having to be replaced in the future journey to net zero.*

Figure 6 – Fabric First principles



Your stock

As has already been mentioned, in some organisations, stock condition data is poor and further validation and data collection is required. Whilst a property archetype approach based on SAP Appendix S (which relates to original Building Regulation periods of construction) is useful, in a sense, behind every front door is a different archetype. A further constraint to improving energy efficiency is the relationship between the external heat loss area and the usable floor area, known as the form factor, and this will vary between similar properties. So data will only take you so far and feet on the ground are needed.

Figure 7 - RdSAP Table S1 Age bands

Year of construction			
Age band	**England and Wales**	**Scotland**	**Northern Ireland**
A	before 1900	before 1919	before 1919
B	1900-1929	1919-1929	1919-1929
C	1930-1949	1930-1949	1930-1949
D	1950-1966	1950-1966	1950-1973
E	1967-1975	1967-1975	1974-1977
F	1976-1982	1976-1983	1978-1985
G	1983-1990	1984-1991	1986-1991
H	1991-1995	1992-1998	1992-1999
I	1996-2002	1999-2002	2000-2006
J	2003-2006	2003-2007	(not applicable)
K	2007-onwards	2008-onwards	2007-onwards

Occupied Properties

Unless a retrofit strategy is led by voids, which will not deliver the programme or scale required, every property is someone's home.

Working with residents in occupation means that compromise is required, and all elements of a deep retrofit fit might not be possible. An incremental approach may be the most appropriate. Above all, residents' consent is required, so pre-works and post-works information and engagement strategies are vital.

Supply Chains

Unfortunately, the supply chains required to deliver the scale of retrofit needed are not yet in place. Organisations must consider procuring longer term partnerships with large scale retrofit programmes in mind.

Funding

In relation to funding, a split incentive exists between landlords who fund work and residents who benefit from the investment through lower bills. Challenges also exist in recovering the cost of works from leaseholders and this needs to form part of your overall strategy.

In some instances, models do exist to address these challenges. For example, the **Energiesprong** model, where works are funded through capital spend with capital paid back through resident energy savings via a comfort plan, may work in some circumstances, but not necessarily in all.

The government views social housing as a pump primer for retrofit in the wider market and, over the years, has provided funding to undertake programmes of work.

However, social landlords may choose to look at retrofit investment through the lens of social value and account for a return on investment by including added social value within their communities such as employment, increased disposable income or wider environmental metrics.

Leadership

With social housing providers having so many competing priorities, particularly building safety, strong and committed leadership towards the longer-term objective of retrofitting existing homes is required, otherwise organisations run the risk of being left behind, unable to catch up and potentially failing.

PAS 2035: 2019 RETROFITTING DWELLINGS FOR IMPROVED ENERGY EFFICIENCY – SPECIFICATION AND GUIDANCE

PAS 2035 provides a risk-based quality control system for the energy retrofit of homes and best practice guidance about domestic retrofit projects.

It supports the TrustMark government-endorsed quality scheme and allows users to claim compliance with it. The PAS identifies roles within the retrofit process, for example a retrofit coordinator, which are specifically qualified to undertake different aspects of the retrofit process.

The PAS was introduced to address issues of poor quality in previous retrofit works and to avoid unintended consequences of retrofit such as dampness and condensation within homes. It has been adopted by the government where funding is provided and, if specified by clients, gives assurance that retrofit works will achieve their desired outcomes.

Figure 8 - Who does what in the new process?

				PAS 2030 (2019)		
Assessed Project Risk	**Assessment**	**Strategy**	**Design and Specification**	**Installation**	**Handover**	**Monitoring/ Evaluation**
A (Low)	Assessor, Coordinator	Coordinator	Coordinator, Designer	Installer	Installer	Coordinator, Evaluator
B (Medium)	Assessor	Coordinator	Coordinator, Designer	Installer	Installer	Coordinator, Evaluator
C (High)	Assessor	Coordinator	Designer	Installer	Installer	Coordinator, Evaluator

Coordinator

Temporary whilst Evaluators are trained and accredited.

Advanced Evaluation can not be performed by the same coordinator leading on the wider project

Indicates “oversight”

PAS 2035 requires early engagement through key pre-works surveys such as condition reports, options evaluations, and production of **medium-term improvement plans.** In future, such plans are likely to form part of digital **'building renovation passports'** containing all information about a building.

Project personnel must be qualified to fulfil the various PAS 2035 roles such as Retrofit Designer, Retrofit Assessor, Retrofit Coordinator, Retrofit Installer and Retrofit Evaluator. Documentation is collated by the Retrofit Coordinator who confirms compliance and uploads data to a central hub called the Data Warehouse. This allows for easy access to lessons learned, collaboration, and sharing of knowledge within organisations and for future schemes.

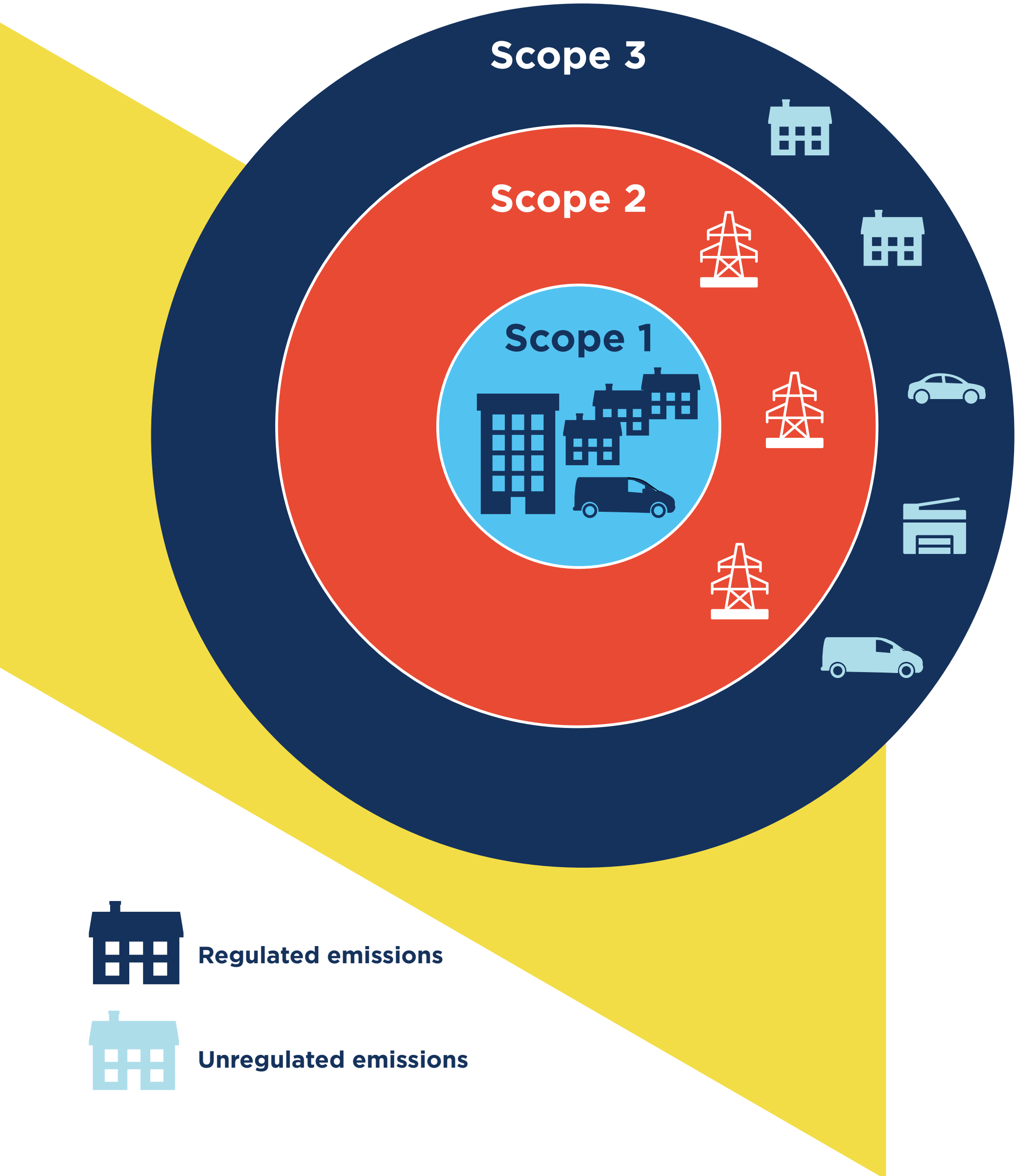
PAS 2035 insists on ventilation and moisture control strategies being developed at an early stage of the design. Compliance tools such as those available from The Retrofit Academy (more detail on their website **here**) ensure that the Retrofit Coordinator tracks the issue of key documentation and key hold points through the project. A PAS 2035 scheme must meet certain requirements depending on the level of risk assessed as part of that project (risk paths A – C). This informs the general approach and compliance requirements, as well as levels of monitoring, and pre-, mid- and post-works surveys and testing.

Certification, such as MCS accreditation, must be held by approved installers and all this information is presented to the Retrofit Coordinator to confirm compliance. In taking a fabric first approach, key upgrades to the building envelope are achieved ahead of the introduction of new energy generation systems, thereby reducing demand. In assessing both ventilation and moisture control impacts of measures, some of the worst failings of historical retrofit jobs are mitigated. It is likely the PAS 2035 and PAS 2030 standards for installation will be adopted for all publicly funded retrofit refurbishment projects going forward.

Figure 9 - Aims of PAS

YOUR ORGANISATION'S STRATEGY

Figure 10 – The scope of your organisation's carbon emissions



Your organisation's carbon footprint will sit in:

- **Scope 1** - the activities you are directly responsible for including your offices, vehicles and the emissions from residents' use of regulated energy in their homes e.g. gas boilers.
- **Scope 2** - the emissions produced by energy suppliers resulting from your residents' and your own use of energy.
- **Scope 3** – the emissions indirectly resulting from your supply chain, staff commuting and your residents' use of unregulated energy, for example in their electrical appliances.

Your organisation can directly control your Scope 1 emissions and thus influence your Scope 2 emissions. Scope 3 emissions can be managed by your procurement policies and influencing behaviour. A way of allocating emissions arising from your residents' homes might be to calculate the regulated emissions predicted by your energy data and subtract from actual emissions from sampled bill data or monitoring feedback. *Some organisations consider that only energy they directly buy or sell sits within their scope 1 emissions.*

The strategic choices facing organisations in a net zero future are a myriad but can essentially be summarised as:

- What are your strategy drivers?
  - > To improve your stock data
  - > To reduce residents' fuel costs and increase comfort
  - > To lower your overall carbon footprint
  - > To comply with legislation
  - > Other metrics?
- Do you wish to achieve EPC C ahead of the legislative timetable?
- Can your organisation accommodate the costs alongside your other asset objectives?
- What technologies are your organisation and your residents likely to accept and how much risk of adoption or non-adoption are you willing to accept?
- Are you ready to maintain this type of asset?

It may be useful to overlay your strategic business plan with these questions including strategic asset management and planned investment programmes, model retrofit briefs, procurement strategies, competency and training, resident engagement, social value objectives and digital capability.

Residents and soft landings

It is easy to formulate a retrofit strategy for an organisation based upon cost, programme and performance metrics but our experience is that residents must be central to any strategy.

Apart from **voids**, most retrofits will be taking place in occupied homes and will involve disruption for residents. Following retrofit works, residents may often be required to adapt the way they use and operate their home.

A clear engagement strategy is required that effectively communicates why the retrofit is being undertaken, what it will involve, how long it will take and what the benefits are for residents. The strategy is likely to involve local staff on the ground, contractors, resident liaison officers, road shows, newsletters, resident promoters and champions, and comprehensive user guides. Our experience is that dropout rates of 50% from programmes of retrofit are the norm and a comprehensive strategy is required to minimise this dropout rate.

Retrofit design that focuses on passive measures is preferred, but where new technologies are installed, clear and concise guidance on how they work and how they should be used must be provided. This should be followed up after a period of use to check things are still working correctly. In commercial property, this type of approach is known as **'soft landings'** and is used to minimise the performance gap between the intended design performance and actual performance.

Many technologies now exist which will show residents how their homes are performing and report performance to landlords so that support may be provided to residents. Using the SMETRS **(see page 8)** this may allow actual performance to be determined.

Putting residents at the centre of your strategy is more likely to achieve the targeted programme and performance outcomes.

Figure 11 - Clarion Social Housing Decarbonisation Fund (SHDF) demonstrator project

Clarion site review

Strategic Asset Management

Retrofit strategies should take place within a strategic asset management strategy which coordinates asset planning and business planning (see **Figure 12**). Using their asset systems, social landlords should be able to identify poorly performing properties and archetypes in geographical areas and formulate retrofit works packages to meet their strategic objectives. The strategy is likely to lead with fabric first and trialling clean heat and contain **deep retrofit** specifications for freehold voids, **shallow internal retrofit** for leasehold voids and programmed works to the worst performing properties.

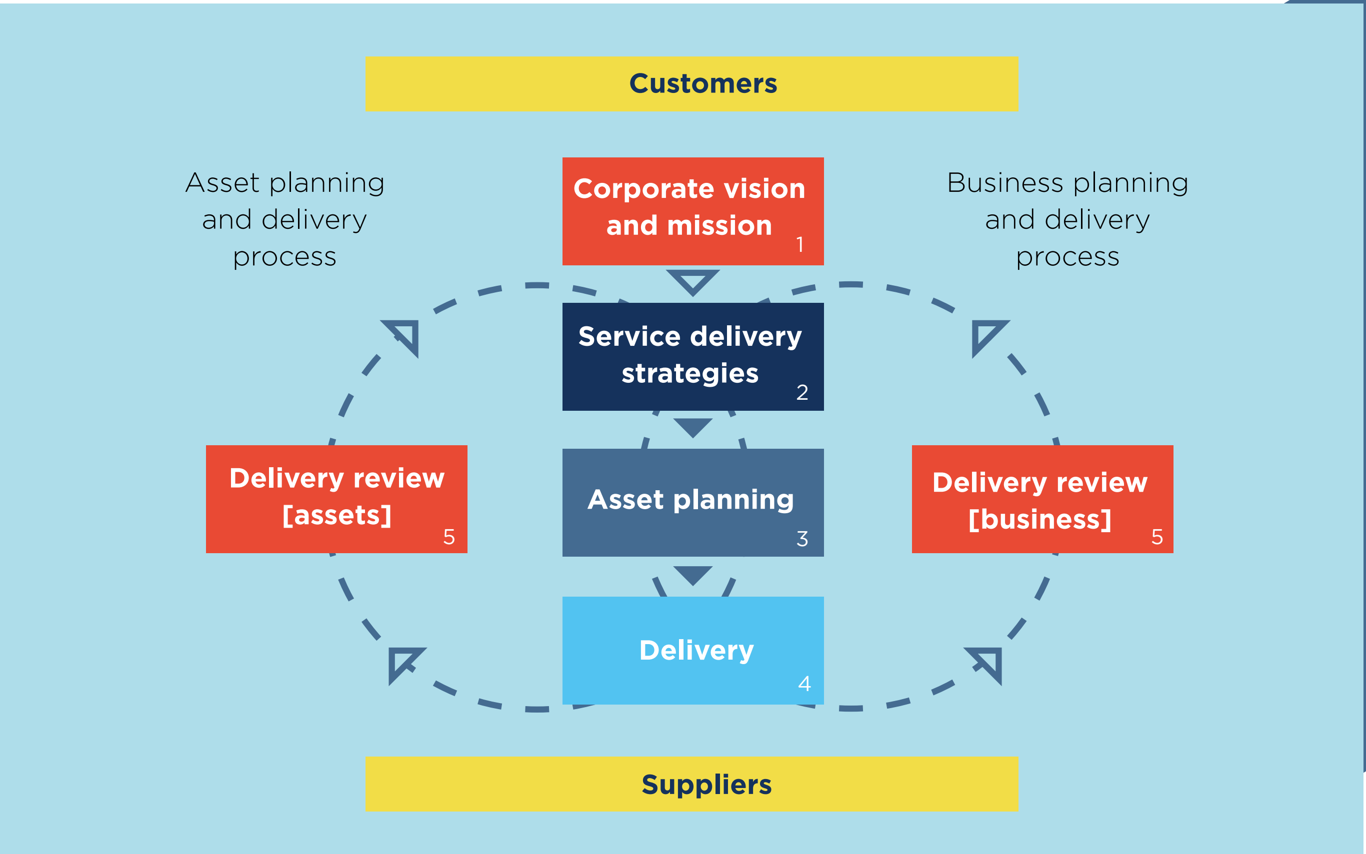
However, this cannot be distinct from a landlord's condition-led planned maintenance and component replacement cycles. Components and elements that would be replaced or upgraded as part of retrofit works to achieve performance criteria (high EPCs) may have a significant element of useful economic life remaining. Replacing them early is not only "wasting" the embodied carbon they represent but is not economically viable. Energy efficient measures such as external wall insulation are often linked to other components such as windows and doors, making them difficult to retain even if there is economic life remaining.

Therefore, the retrofit strategy must be integrated with planned maintenance and replacement cycles to determine when component replacement is best undertaken on a balance of cost and carbon. The challenge for organisations is to achieve a cultural shift to strategic asset management which applies weighting to condition, embodied carbon, improvement in operational energy efficiency and resident amenity, to drive programmes of planned maintenance and replacement including retrofit.

Such a strategy is likely to include programme replacement of non-energy related components (kitchens, bathrooms, fire safety works etc) and replacement and upgrade of energy related fabric elements prior to installation of ventilation and/or low carbon heating and hot water appliances. Developing and currently unknown technologies will appear which will change a strategy, so any strategy must be flexible and capable of modelling "what if" scenarios.

PAS2035 requires that each property has a "medium term improvement plan" on completion of the works which identifies the work required that will get as close to a nearly zero carbon building as possible. When aggregated across a stock, this approach is one that could form the basis of a strategic asset management strategy. It might also identify properties that cannot be practically, or cost effectively, retrofitted and might form part of a stock replacement or regeneration approach.

Figure 12 - Strategic asset management process



RICS Strategic public sector property asset management - 3rd Edition September 2021

Property Selection and Procurement

In larger programmes of work, property selection will be governed by a number of factors including archetypes and built form. In terms of scale and procurement, grouping similar properties together in geographical locations is likely to lead to lower costs as a result of economies of scale and lower overheads and preliminaries.

Pilot projects to learn lessons on specific archetypes and technical solutions are useful but it is likely that this work has already been done elsewhere in the sector.

To assist in this grouping using asset systems, it is helpful to think of properties as standard and non-standard. Non-standard properties are those that might have complex detailing or heritage features, are within conservation areas or have planning constraints and/or are of non-standard construction. Such properties are likely to have cost and time related premiums.

Supply Chain and Skills

In an expanding retrofit market, organisations will be competing for a limited pool of skilled resources. Organisations should mitigate for this to avoid cost uncertainty and potential quality issues and plan ahead.

The standards and roles set out in PAS2035 and PAS2030 should be clearly understood and specified with the correct accreditation. Organisations may choose to train their own staff and those within their direct labour organisations.

Longer term collaborative contracts with experienced partners, which are designed with retrofit in mind and have skills and training requirements explicitly defined including local employment initiatives, are likely to be very beneficial. The same opportunities for training and upskilling will also apply to Direct Labour Organisations.

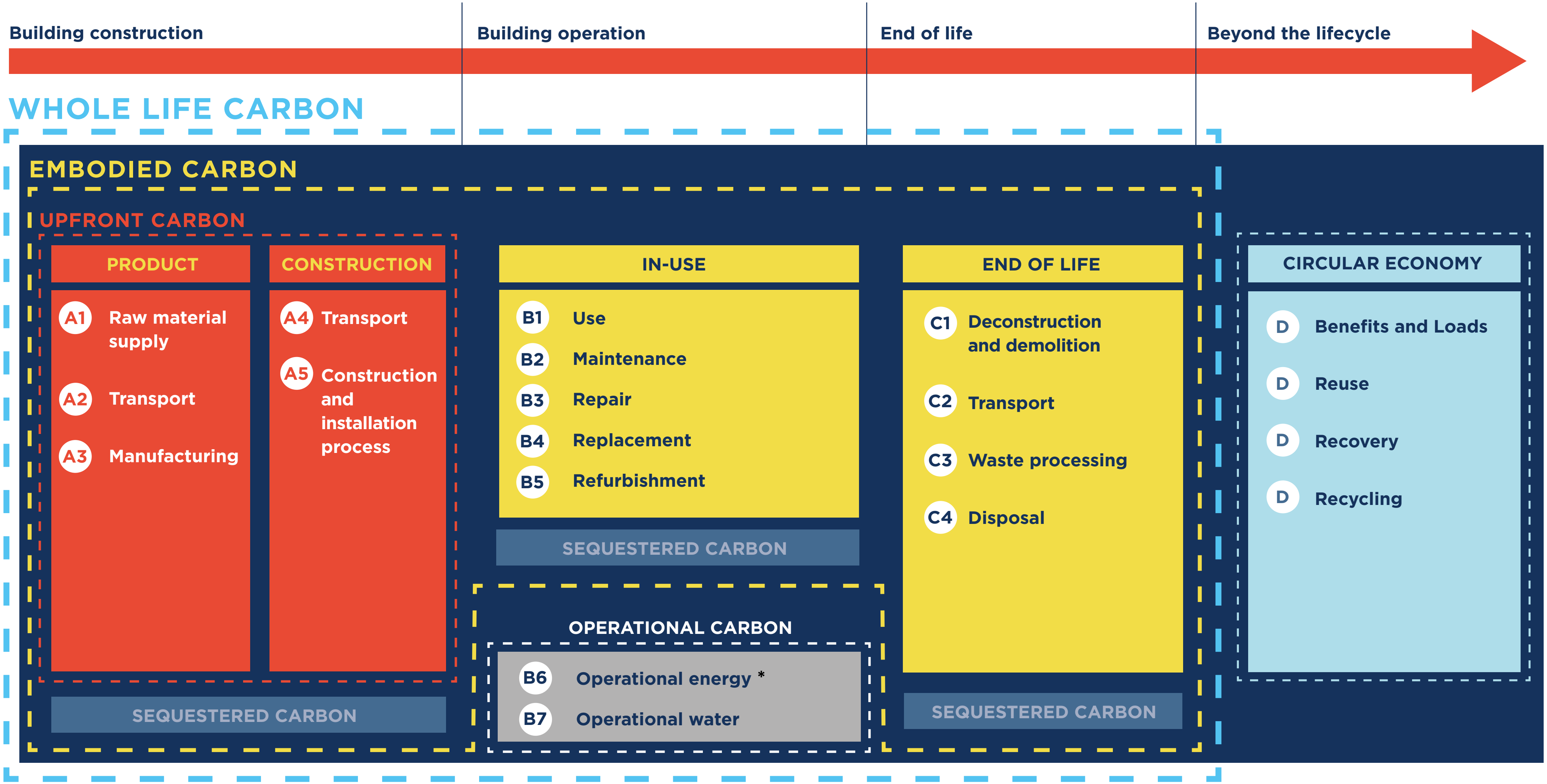
Whole Life Carbon

As we move to net zero, organisations will have to consider and account for whole life carbon. In new build, due to the number of materials used, up front carbon in the form of material production and construction is significant. In retrofit, whilst much of the material and the embodied carbon associated with its original production is retained post retrofit, components and elements removed before the end of their useful economic life (e.g. gas boilers) will affect whole life carbon. Recycling of materials within a circular economic model is beneficial, but organisations might choose to start framing consideration of their stock in terms of the whole life carbon. The RICS Whole Life Carbon Assessment document can be useful in formulating a strategy.[2]

Carbon sequestration (see **figure 13**), which is often targeted through the use of timber products, must be very carefully considered. Timber must originate from sustainable sources. What happens to the timber at end of life is considered in stage D beyond the building life cycle. Also, harvesting and processing timber releases a 'spike' of carbon into the atmosphere, whereas sequestration occurs gradually, over 40-60 years.

2. RICS whole life carbon assessment for the built environment - first Edition November 2017. See **Figure 13** - Whole life carbon assessment model

Figure 13 – Whole life carbon assessment model



The table above, adapted from an image originally created by London Energy Transformation Initiative (LETI), illustrates the differences between the different aspects of zero carbon.

***This toolkit is concerned with B6 'operational energy' carbon following the retrofit of your homes. However, it also considers B2-B5 in relation to strategic asset management and planned investment and asset maintenance**

FABRIC FIRST APPROACH AND POTENTIAL TECHNOLOGIES

As discussed, retrofit is generally predicated on achieving a well-insulated building envelope known as "fabric first".

By retrofitting the existing home to produce a high performing external envelope with well insulated walls, high performance doors and windows and efficient junction detailing between them, the heat needed to keep the property comfortable is much less and building services do not need to produce as much energy.

As a result, **air tightness** (measured in cubic metres of air per square metre of building envelope per hour – *$m^3/(h.m^2)$@50Pa* needs to be better, so that heat is not lost through a draughty building. In the calculations within this toolkit we have used a value of *5 $m^3/(h.m^2)$@50Pa* which is a challenging target. This can lead to more complex forms of ventilation such as mechanical ventilation with heat recovery (MVHR) or centralised mechanical extract ventilation (CMEV) with intelligent trickle vents which open and close dependent upon humidity.

Lower heat demands will suit technologies such as air source and ground source heat pumps which can run at efficiencies of more than 300% (compared to 89% for traditional gas condensing boilers). Such technologies do however require residents to consider how they operate their home heating systems and perhaps adapt their behaviours to maximise the potential of this approach.

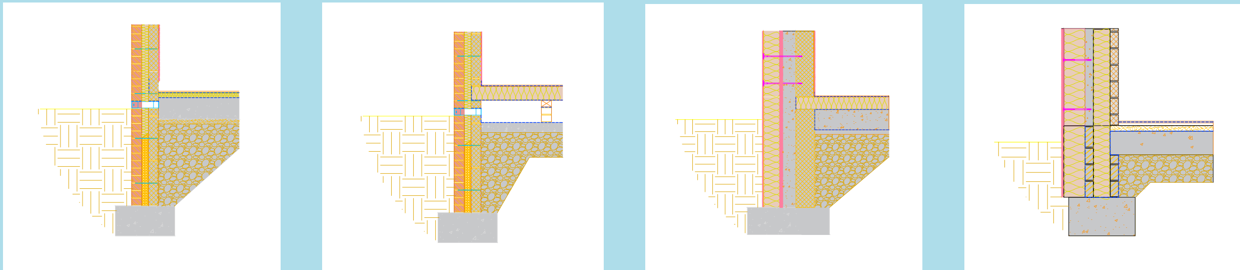
Elemental Build Ups and Values

Every home is different but based upon building regulations periods defined in RdSAP (see **figure 7**), the archetype surveys and our own experience we have developed typical floor, wall and roof build up details for the Archetypes as shown in **Figure 14**. These typical build ups are shown in more detail in **appendix 2**.

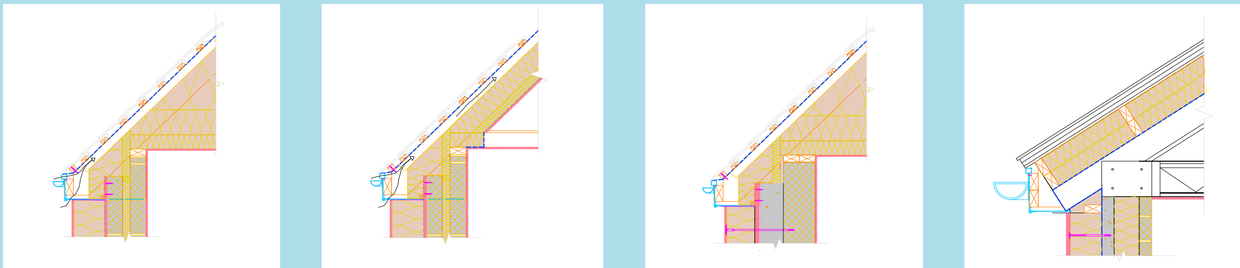
They represent details and build ups that can be achieved with current materials to achieve a fabric first approach.

Figure 14 – Element build up selection

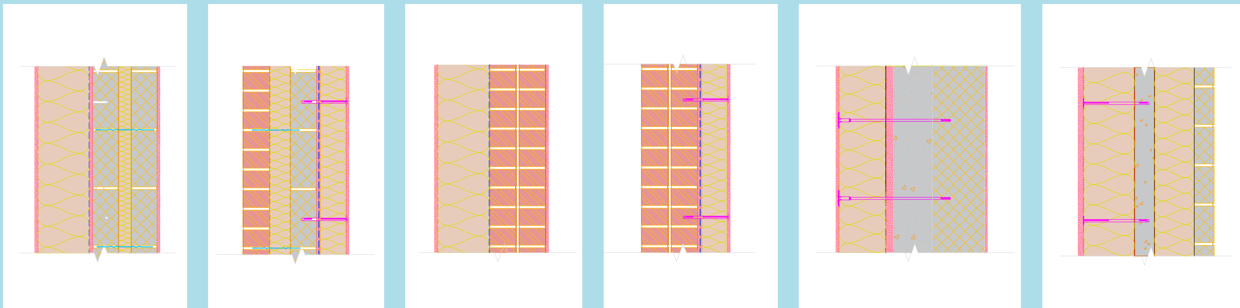
CLICK HERE to see more information on **Floors**.



CLICK HERE to see more information on **Roofs**.



CLICK HERE to see more information on **Walls**.



Thermal Bridging and Condensation Risk

A thermal bridge is where there is a direct connection between the inside and outside of the building through one or more elements that are more thermally conductive than the rest of the building element. As a result, there will be wasteful heat transfer across this 'bridge' and its internal surface temperature will be lower than other better insulated internal surfaces. Condensation may occur where warm moist internal air comes into contact with the cold surface resulting from the thermal bridge and this may result in mould growth.

When following a fabric first approach, the avoidance of thermal bridges is desirable. A classic example of a thermal bridge is at damp proof course (DPC) level where the external wall insulation (EWI) does not extend to ground level and below. In many property types this will create a thermal bridge at the ground floor junction and potentially cause condensation and dampness inside.

BRE information paper 1/06 (IP 1/06 Assessing the effects of thermal bridging at junctions and around openings) identifies a method for determining the risk of this occurring and PAS2035 identifies a minimum temperature factor for this of 0.75 fCRsi. As can be seen from the thermograms in **figures 15 and 16** the addition of below ground insulation has raised the surface temperature factor value above 0.75.

In PAS2035 compliant projects, the need to avoid such a thermal bridging condition can generate significant additional costs. On some of our projects, (see **figure 18**) additional costs to excavate, install EWI, realign and replace drainage etc. have resulted in costs of more than £5,000. On the Clarion SHDF project on Wimpey No Fines properties, an insulated starter track has been used to terminate the EWI avoiding the need to extensively excavate (see **figure 17**).

Figure 15 - Suspended timber floor with no below DPC EWI

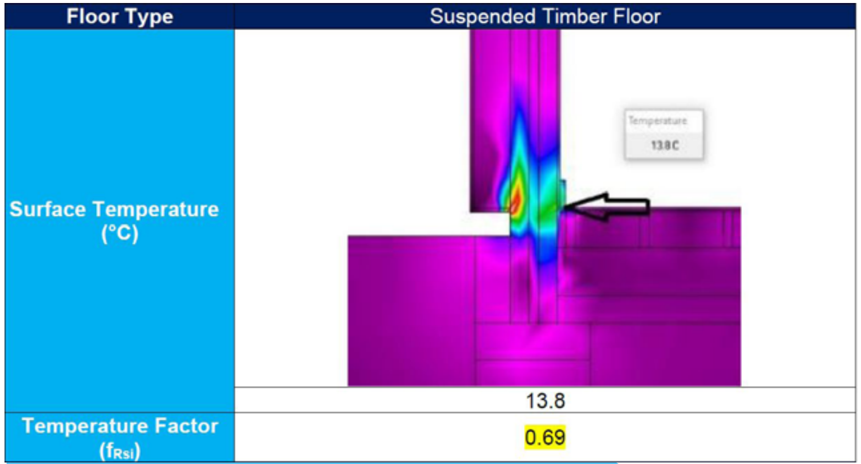


Figure 16 - Suspended timber floor with below DPC EWI

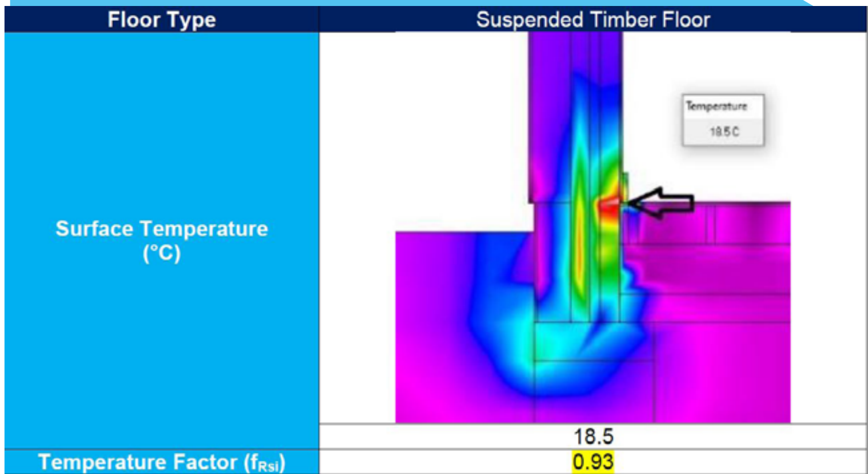


Figure 17 - EWI starter track

Figure 18 - Excavation for EWI

Thermal Bridging and Condensation Risk

The thermograms shown in **figures 19 and 20** are from modelling undertaken on Archetype 7 and are examples of the typical thermal bridging calculations undertaken to achieve the reduction in SAP scores and predicted kWh/m²/hr values. The thermal modelling may result in details being finessed or additional insulation being added, e.g. EWI below DPC.

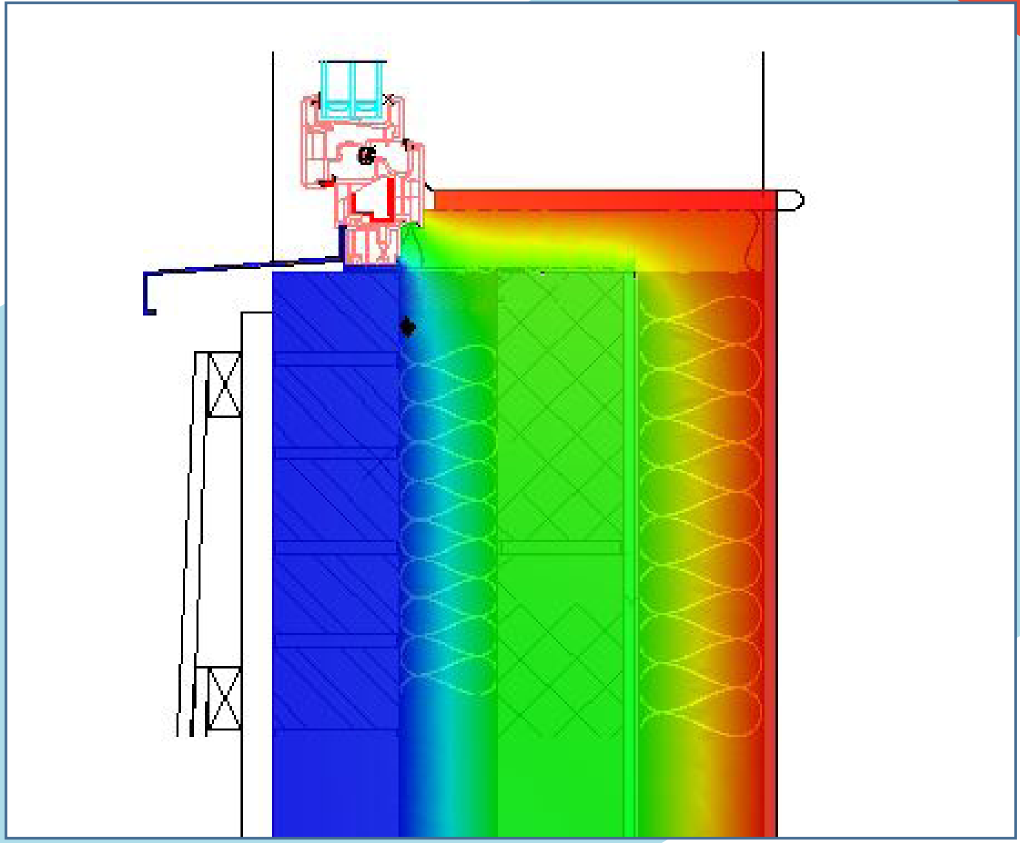


Figure 19 - Thermogram of bespoke thermal bridge calculation at eaves level

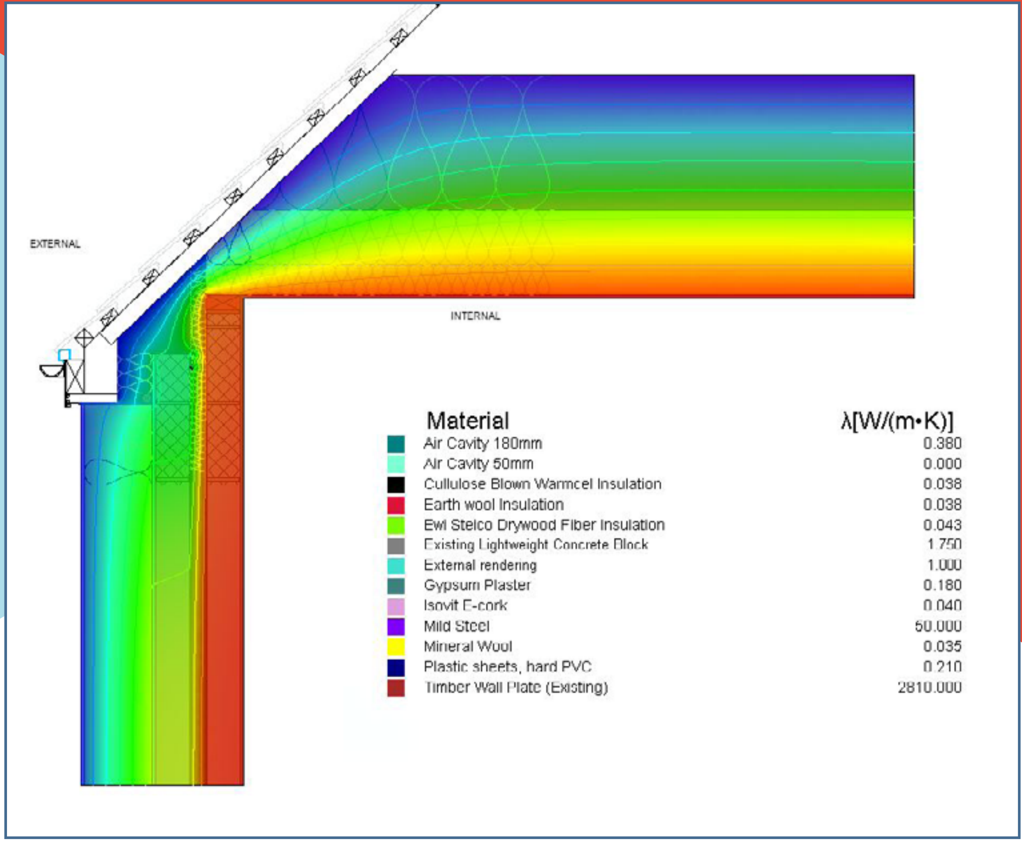


Figure 20 - Thermogram of bespoke thermal bridge calculation at window cill level

Air Tightness and Air Quality

To achieve the lower levels of air tightness required by fabric first approach, a retrofit may rely on the existing fabric, particularly in the case of wet masonry construction with solid floors, with penetrations through the fabric being sealed. In some property types, additional air tightness measures such as liquid applied membranes or tape may be required at the external envelope junctions with new components and elements such as windows. In other types, an applied liquid membrane might be required to all external façades. Careful attention to existing service runs, elements, junctions etc. is required.

The increase in air tightness of a "leaky" but well-ventilated building can create significant risks of poor indoor air quality, dampness, condensation and mould growth if a bespoke ventilation strategy, complying with the risk paths in Building Regulations Part F and identified in PAS2035, is not implemented.

However, retrofitting systems such as MVHR into existing dwellings can result in significant disruption and loss of space for residents, so careful thought should be given to the types of systems, their location and the need to service them to maintain their efficiency.

Figure 21 - Spray applied liquid membrane

Figure 22 - Brush applied liquid membrane

Figure 23 - Brush applied liquid membrane

Figure 24 - Airtightness tape

Figure 25 - simplifying envelope

Figure 26 - Spray applied liquid membrane

Overheating

As our climate warms, overheating is a significant risk and must be considered within the design. This will include the design of ventilation systems, the **G-values** of glazing and incorporating the **thermal mass** provided by the existing structure, orientation, shading, number and location of windows and levels of site exposure.

Figure 27 - DMEV

Figure 28 - MVHR

DESIGN IMPLICATIONS

Loss of Space

One of the main concerns of residents, in relation to retrofit, will be the change to the amenity of their home, how they live in it and, in practical terms, loss of storage space e.g. additional roof insulation may limit access and storage in lofts.

Generally, additional external insulation may restrict access routes to the property and compromise may have to be made in insulation thickness in certain areas such as side and shared access routes. Internal insulation will be very disruptive for residents and will reduce overall room areas and so is not particularly welcome. It will also involve discussions about internal decorations and floor coverings. However, it may be necessary in limited circumstances where there are heritage or planning implications.

Low carbon technology such as air source heat pumps (ASHPs) will require a **smart cylinder** which will remove internal storage or potentially take space from existing rooms and, taken cumulatively with other technologies, can result in the perception of a significant loss of inside space.

These issues should be addressed directly pre-works with a clear explanation of what is proposed and what are the outcomes. It may be possible to use external service pods to address these issues, but the market for this is relatively immature.

Figure 29 - Loss of internal space

Figure 30 - use of aerogel insulated track to avoid reducing external access

Drainage, Complex Detailing and External Services

If the proposed retrofit specification includes EWI, the need to replace or re-align rainwater pipes and soil and vent pipes connected with those below ground can be costly, prolong programme and cause additional disruption to residents.

Specific property details at roof eaves level and external features such as bay windows can create difficulties, in particular at roof level where adjustment of roof lines may be required to accommodate EWI and stock products are not available. *Whilst many landlords will favour non-combustible insulation such as mineral wool due to its inert nature, less inert material can provide the same thermal characteristics with less thickness. This may avoid the need to re-detail roof junctions and therefore lower costs.*

If there are any statutory service connections fixed directly to the outside of the building, re-siting of these can be costly and have significant programme effects and require very early liaison with statutory authorities.

Comprehensive pre-works surveys on a property-by-property basis, which is a pre-requisite of PAS2035, are recommended to mitigate such risks.

Fig 31 - Drainage connections

Fig 32 - Non standard detailing

Figure 33 - Building complexity

Planning Considerations

Changing the external appearance of homes, particularly with EWI can be unacceptable to Local Planning Authorities who may require properties to be completed in pairs or groups. In mixed tenure neighbourhoods this can be problematic. This can sometimes be overcome using brick effect finishes but these often add additional cost with no retrofit benefit.

CURRENT TECHNOLOGIES

Modern Methods of Construction

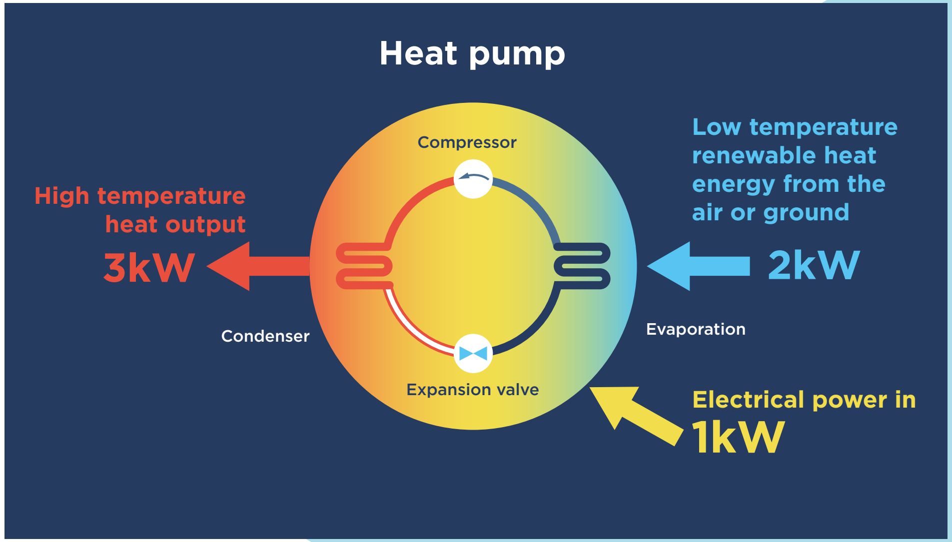
With the scale of retrofit required, the application of modern methods of construction (MMC) to produce economies of scale and efficiency will be required. Panellised insulation systems and premanufactured modules containing low carbon heating and energy storage could speed up programme delivery and reduce disruption and space loss but these technologies are not yet mature in the UK.

Heat Pumps

The most common are air and ground source heat pumps which use electricity to harvest energy from the air or ground into usable heat within the home. Ground source heat pumps use fluid in buried pipes laid horizontally or in vertical piles in the ground to capture ambient ground heat. Laid horizontally this can require a larger external area. Air source heat pumps capture ambient energy from the outside air. Both will generally transfer this using a condensing unit to a hot water cylinder from where it can be used to provide heat and hot water. Air source heat pumps are the most common heat pump but need to be correctly installed providing low temperature heat into an efficient and airtight building envelope. Larger low temperature radiators may also need to be installed. *In this toolkit revision, multi-residential properties have been included, which use a small air source heat pump to boost hot water temperatures.*

Figure 34 – Energiesprong services pod

Figure 35 – Heat pump efficiency



Ventilation

A comprehensive ventilation strategy is required for any retrofit, particularly where airtightness is being improved. To achieve energy performance standards mechanical ventilation with heat recovery is preferred as it extracts warm moist air and passes it through a heat exchanger where it warms incoming fresh air as shown in **figure 36.** However, MVHR ducts can take up excessive space and be disruptive to residents during installation. An alternative system is centralised mechanical extract ventilation as shown in **figure 37**, where warm moist air is extracted, no heat is recovered, and fresh air is drawn in through humidity-controlled trickle vents. Whilst not as energy efficient, this system can be less disruptive to install and take less internal space.

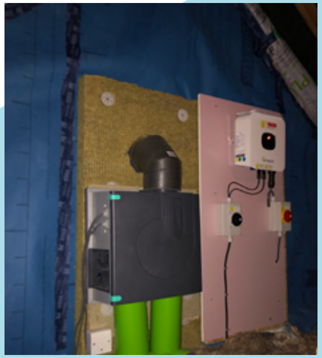


Figure 36 – Mechanical Ventilation with Heat Recovery (MVHR)

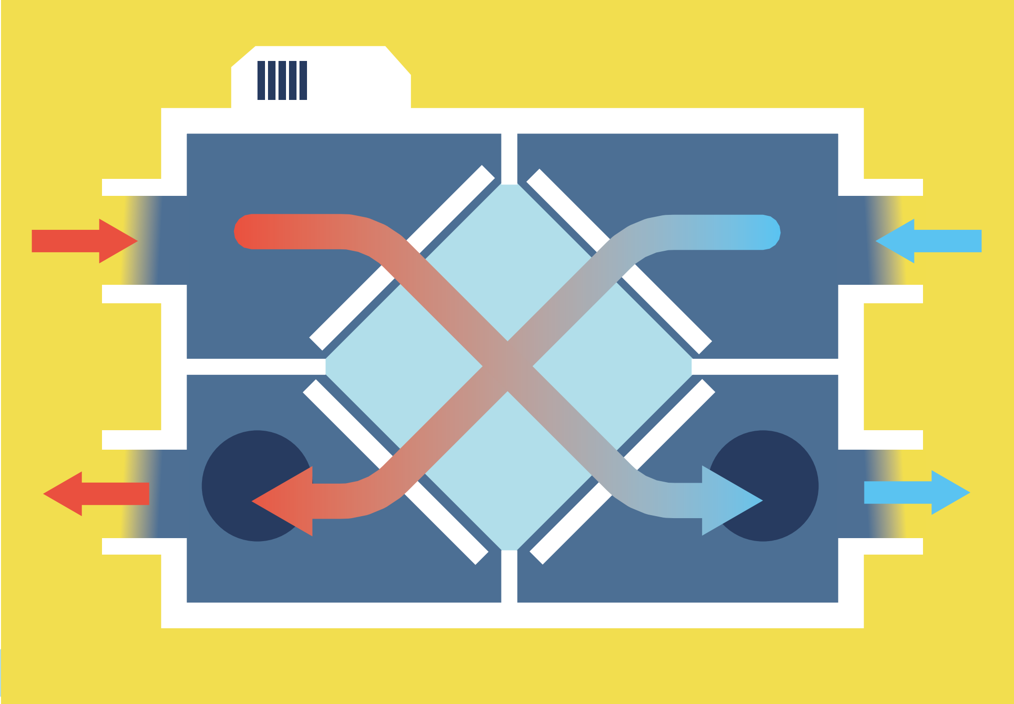
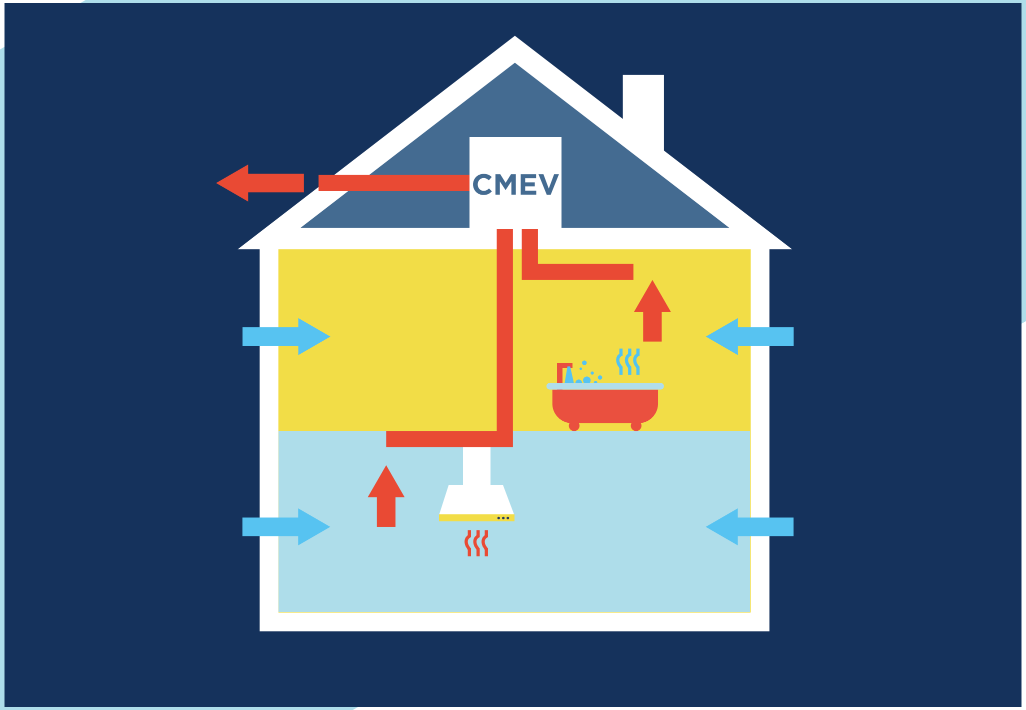


Figure 37 – Centralised Mechanical Extract Ventilation (CMEV)



Intelligent Controls, monitoring and evaluation

A home's heating and hot water system needs to contain controls to ensure that it is operating in the most effective and efficient way and provides occupants with the most user-friendly interface possible. If people can see the energy performance of their home and what it is costing, they are more likely to operate it as intended by its designers. There are now smart control systems available that use sensors and artificial intelligence to allow the building to adapt to occupants' behaviour patterns and use time of use energy tariffs and energy storage in the home to optimise efficiency and even sell energy back to the grid.

Figure 38 – Smart home control systems

Photovoltaic Panels

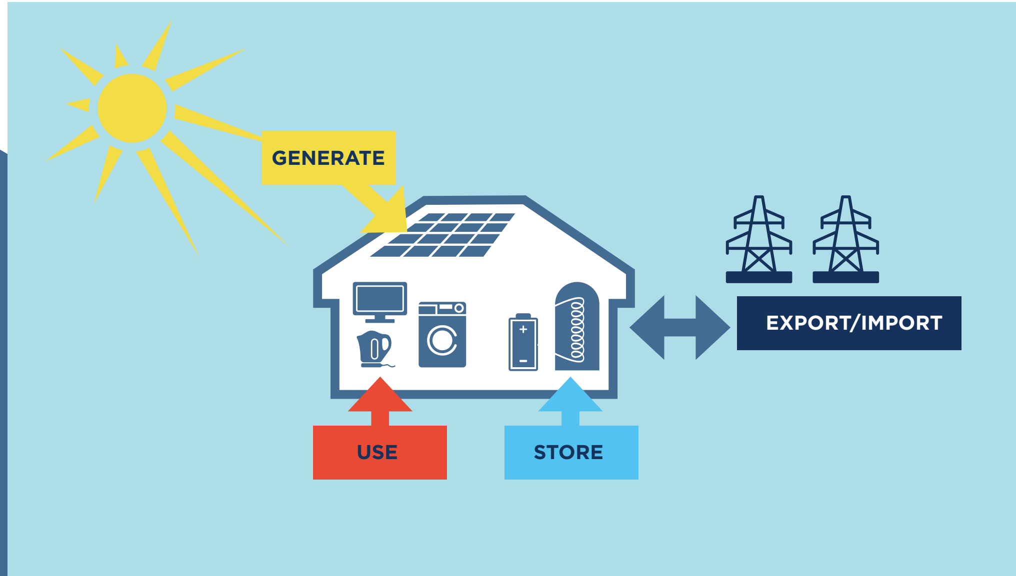
Another common renewable technology is photovoltaic (PV) panels, which are often roof mounted. They generate electrical power which passes through an invertor to convert it to alternating current to use in the home, store as energy via hot water or batteries, or export to the grid. Panels must be carefully sized and take account of orientation towards the sun. They will generate peak power during the day in summer which, with the right system, can be stored in the home.

Figure 39 – PV panels

Energy Storage

A hierarchy of generate, use, store, export should be adopted. This leads to a balance of optimal sizing of solar PV for the available roof and size of property. If residents understand when renewable electricity is being generated, then they may adapt their use of appliances to use energy before it is stored in a smart hot water cylinder or other potential energy storage devices like batteries and electric vehicles. Smart home control systems can also optimise energy storage and interact with the grid by adopting time of use tariffs and intelligent learning of home usage patterns. Lower tariffs, specifically for heat pumps and electric vehicles are under consideration.

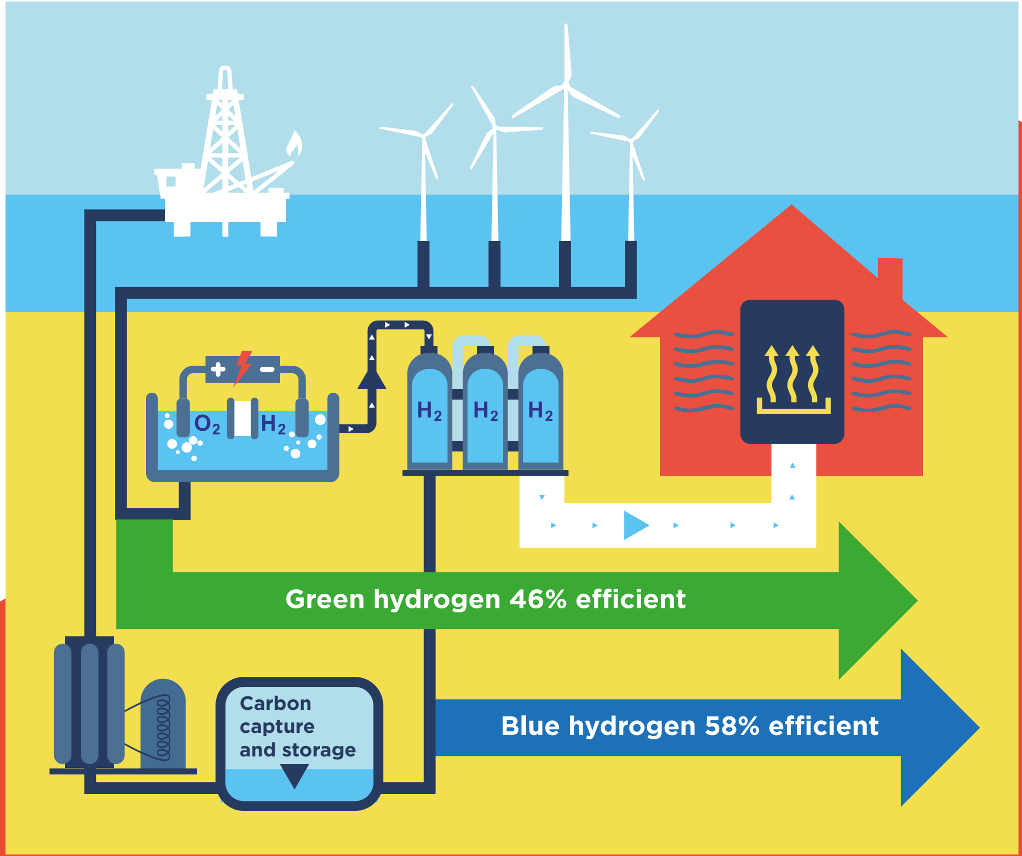
Figure 40 – Optimising energy use



Hydrogen and Green Gas ready boilers

Hydrogen is being promoted as a zero carbon fuel of the future. The idea being that existing gas boilers can be replaced with hydrogen ready boilers so that blue and/or green hydrogen can be supplied in future via a new network or mixed into existing gas supplies to reduce their carbon intensity. Whilst this is an option, it is unwise because hydrogen production is inefficient, as can be seen in **figure 41** so it is likely that hydrogen will be used in other industries, transport or as an energy storage medium. *This is reflected in the government's published hydrogen strategy, the net zero strategy and British Energy Security Strategy which also identified 'pink' electrolytic hydrogen produce by nuclear power.*

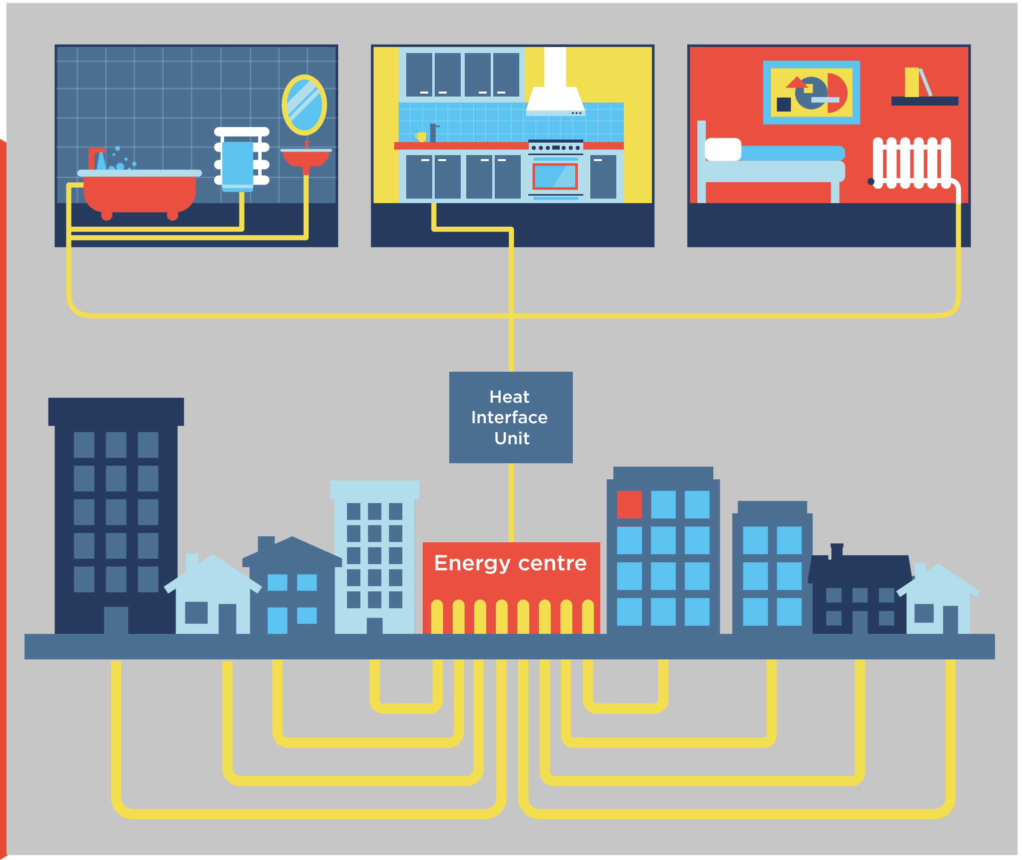
Figure 41 – Efficiency of blue and green hydrogen production



Heat networks

In some locations, heat networks are available or can be constructed so that home heating and hot water can be provided by a heat interface unit (HIU) connected to the network that is supplied by central plant. Such central plant can be very efficient in cost and carbon terms, as shown in **figure 42** but heat networks require scale to spread the cost of the infrastructure among users.

Figure 42 – Energy centre heat distribution



MULTI-RESIDENTIAL BUILDING SERVICES OPTIONS

This revision of the toolkit has added building services options providing space heating and hot water for retrofits in multi residential blocks.

*The circumstances for each block will be unique and require specialist professional design but we have selected options using an energy centre with ground source heat pumps boosted by micro water source heat pumps (**fig 43**), individual air source heat pumps (**fig 44**) and high efficiency electric storage heaters with hot water boosted by a micro air source heat pump (**fig 45**). Heat may be delivered via heaters, radiators or underfloor heating. Photovoltaics are indicative only.*

***Note** – In this revision for the purposes of simplicity and based upon current project experience we have chosen not to model individual air source heat pumps in the archetype modelling as the chosen archetypes were not suitable. However, the next revision will contain a suitable archetype which will be modelled.*

Figure 43 – Ground Source Heat Pump with Water to Water Heat Pump and Heat Store

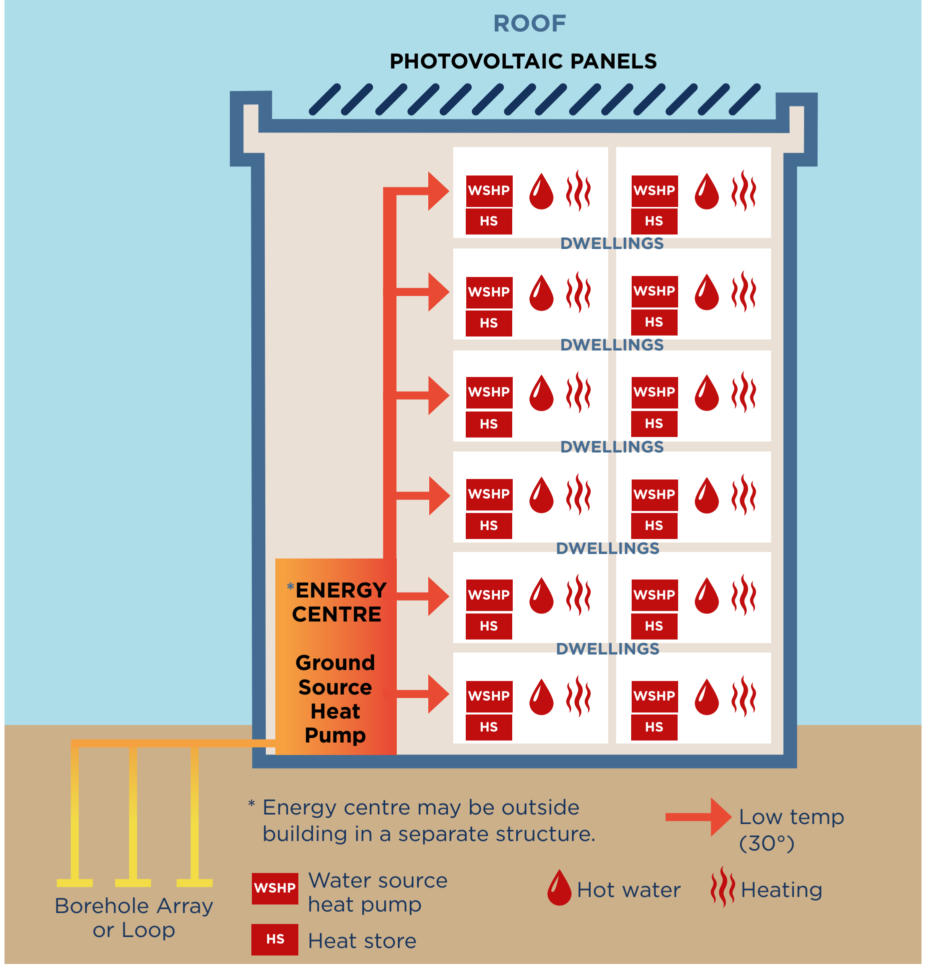


Figure 44 – Individual Air Source Heat Pumps with Internal Hot Water Cylinder

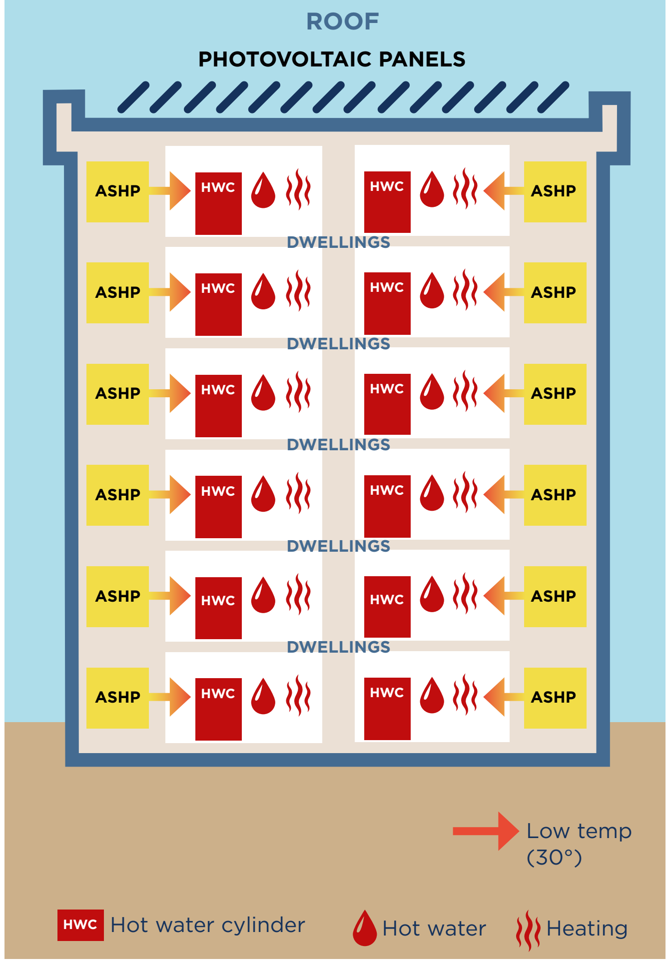
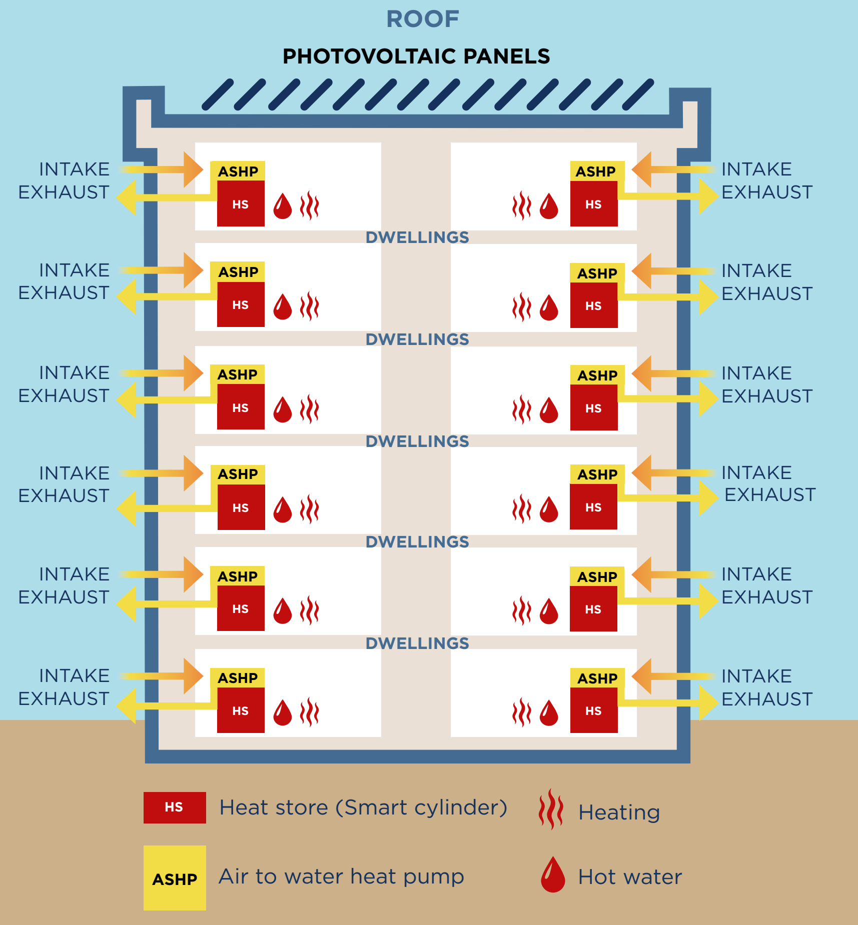


Figure 45 – Electric Storage Heaters and Hot Water Cylinder with Air to Water Heat Pump



YOUR OPTIONS AND POTENTIAL STRATEGIES

What have we done?

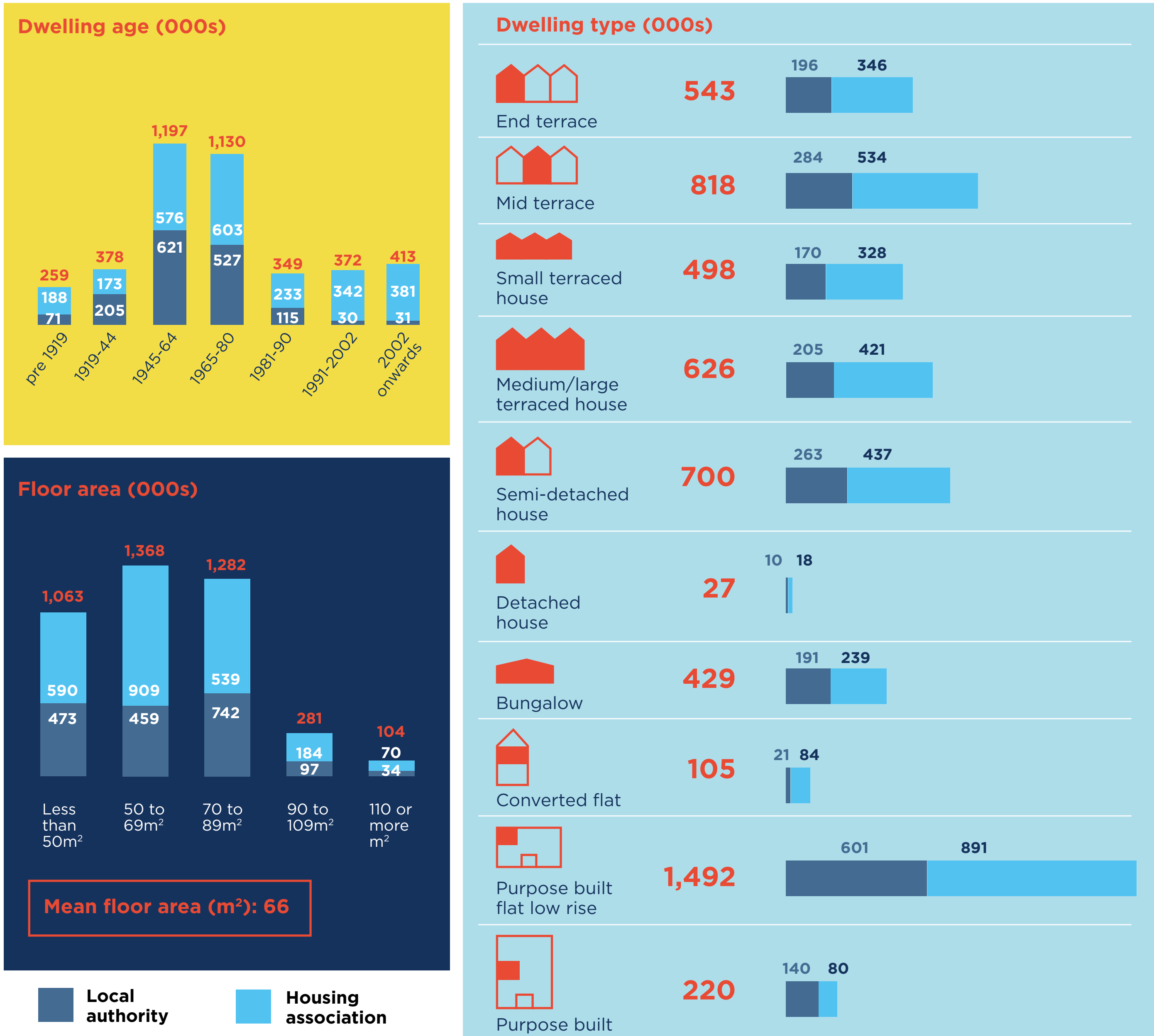
We have analysed the **English Housing Survey** and Appendix S of the Standard Assessment Procedure (see **figure 7**) and used this to identify some commonly occurring social housing building types and forms within original construction age bands.

There are many variations, but these selected property types represent large amounts of the existing building stock. Higher rise flats should be considered on a bespoke block-by-block basis due to their specific safety, fire and servicing characteristics. *However, this toolkit revision now includes some multi-residential types which allow some evaluation of different retrofit options for these archetypes.*

We have taken each of the archetypes shown and modelled them in SAP 10. The base model for each archetype has assumed that:

- existing windows are first-generation double-glazed windows and door is typical solid door
- any existing cavity wall has been filled with poorly performing first generation cavity fill
- loft top up to 200mm has been undertaken
- standard mechanical extract fans in kitchens, toilets and bathrooms
- *A conservative airtightness value of 15 $m^3/(h.m^2)$@50Pa has been assumed*
- space heating and hot water is provided by condensing gas boiler of 89% efficiency.

Figure 46 – Stock profile Social housing sector 2019



2019-20 English Housing Survey Table AT2.1

THE ARCHETYPES

Due to the enlarged number of archetypes, this revision contains a summary table which shows a photo of the archetype and other key information. You can review the summary table and click on the hyperlink for the archetype you are interested in which will take you to the archetype table. You can return to the summary table by clicking on the back button. Alternatively, you can simply scroll through the archetype tables themselves in Appendix 3.

How to use the tables

Each table in **appendix 3** contains a description, photo and plan of the archetype which has been modelled. There are a myriad of different property types and ages, so the archetypes chosen are indicative and only signpost options and costs. Using the same methodology, we will be adding further archetypes to develop a library and typical details from our projects to assist clients and the sector to deliver more quality retrofits, more efficiently.

Each table identifies the archetype and follows a fabric first approach to interventions identifying the intervention, its impact on the EPC rating, SAP score and energy demand. A rate/cost for the intervention and quantities taken from the measured survey generate an intervention cost. Early interventions may be made as the first part of an incremental retrofit with later interventions scheduled in a PAS 2035 medium term improvement plan or strategy.

The tables also identify floor insulation to solid floors as a final intervention because it is deemed to be too disruptive if the property is occupied. In void properties, solid floor insulation may be considered earlier or as part of a deep retrofit.

The cumulative cost column can be used to calculate a partial retrofit by applying the required contingency, OH&P and profit figures. All figures are exclusive of VAT.

The table splits where an option is provided to install CMEV rather than MVHR to reduce disruption and avoid loss of space, but this ventilation strategy would need to be confirmed on specific properties.

SAP vs PHPP and Energy Demand

We have used SAP 10 to calculate EPCs and energy demand (kWh/m^2/yr) but SAP tends to produce lower space heating demand figures than Passivhaus Planning Package (PHPP) software, which has been proven to be more accurate in respect of actual space heating demand. Therefore the figure shown in brackets on the tables is a percentage increase in the SAP derived figure which we believe represents a more realistic figure for space heating demand.

The following notes correspond to the numbered interventions (upgrades) in the tables:

1. **Existing roof insulation** has been assumed to be 150mm mineral wool insulation with a lambda value of 0.04 topped up to 400mm
2. **Existing cavity wall fill** has been assumed to be of poor quality and an allowance has been made for removal and replacement with expanded polystyrene (EPS) bead with a lambda value of 0.034
3. **EWI and IWI** have been assumed to be mineral wool insulation with a lambda value of 0.04. The 200 mm thickness can be reduced to 150mm, without significant detriment to results, if site constraints require. *As noted earlier, organisations may choose to use an EPS insulation material which could achieve the same performance for less thickness.*
4. **Double glazing** *with a whole window U-value of 1.0W/m2K has been used. This is a relaxation from the previous toolkit where triple glazing with a whole window value of 0.8 W/m2K was used. Current project experience is Double Glazing can achieve the 'fabric first lowest regrets' outcome to achieve nearly net zero at a lower cost.*
5. **Airtightness measures** are based upon an existing value of 15m^3/(h.m^2)@50Pa reduced to 5m^3/(h.m^2)@50Pa based upon a combination of measures including liquid applied membrane, tape and specific air loss path sealing. Some archetypes will have a lower starting value and require less works. *Again, current project experience is that this can be relaxed to 8.0m^3/(h.m^2)@50Pa and the desired 'fabric first lowest regrets' outcome of nearly net zero can be achieved.*
6. The cost shown per archetype is to allow for the adaptation of bespoke **thermal bridging** calculations carried out on first archetype where a typical number would be between 5 and 7 calculations per initial archetype.
7. **Floor insulation** has been assumed to be 50mm XPS insulation board with a lambda value of 0.031. Where timber floors are present 150mm of netted mineral wool insulation with a lambda value of 0.04 has been allowed. *These values can also be achieved via a proprietary system, remotely spray-applied insulant, where access to the floor void is possible from inside or outside the property.*
8. **CMEV** values in SAP calculations and costs are based upon a unit with a specific fan power of 3.25 W/l/s at 55°C **MVHR** values in SAP calculations and costs are based upon a unit with a specific fan power of 0.47W/l/s and a heat exchanger efficiency of 80%.
9. **ASHP** values are based upon a smart cylinder size of 180litres with a standing heat loss factor of 1.4kWh/day and water heating efficiency of 295%. The Seasonal Coefficient of Performance (SCOP) is 3.25 at 55°C.

Costs

We have taken our cost data from our own retrofit projects and wider industry data. The archetype tables identify the lump sum cost for the identified measure for that archetype based upon the rates and the quantities taken from the measured energy survey of the specific property. The table shows the individual lump sums, a running cumulative total and a running cumulative total including additional costs identified below.

In this revision we have included a ***whole life cost*** *column in the archetype tables for elements and components based on a 60 year life. The maintenance and replacement costs over 60 years are based upon a* ***Net Present Value (NPV)*** *methodology. The costs shown, if invested today, allow for replacement of the component or element based upon the manufacturers typical stated lifecycles. These whole life costs are in addition to the initial capital costs.*

Whilst initial capital cost will often be the primary consideration alongside whole life carbon the whole life cost may also be taken into consideration as part of business planning.

Retrofit contains inherent risks and unknowns in structure and condition. Our experience is that a client-side contingency is required to account for this, and we have allowed 10%. Clients may choose to vary this dependent upon their confidence level in their archetype information and their supply chain relationships. Crucially, the archetype complexity, in terms of detailing, construction, building services and planning constraints, will affect the level of contingency applied.

We have also applied overheads, profit and preliminary percentages based upon data from our own projects and wider industry data. Clients may choose to adjust these percentages based upon their own projects and supply chain relationships. The chosen percentages can be applied to the cumulative totals on the tables.

Costs have been calculated based upon a default location (information taken from the BCIS) and clients can refer to the location factor table (Figure 44) to adjust costs based upon the archetype's location.

Generally, the fabric first measures should be considered as a holistic package with measures being carried out together (plus a bespoke ventilation measure) preparing the home for the installation of low carbon heat.

The Cumulative Total £ column, including contingency, overheads, profits and preliminary percentages, allows clients to see where they might wish to stop work with further works being carried out later in accordance with a medium term improvement plan.

The thermal bridging bespoke values input, resulting from the prior fabric first measures, may adjust the junction design and may result in a requirement to install EWI below DPC to prevent a thermal bridge and non-compliance with PAS2035. This cost is shown as an extra over in the archetype specific notes.

The costs allowed for the ventilation system are for CMEV for flats and MVHR for houses. Where a CMEV unit is used it is the same model for all archetypes but the cost varies slightly based upon floor area. Where an MVHR unit is used it is the same for all archetypes but the cost varies to greater degree based upon floor area. The costs for the heat pump vary dependent upon property size and include an allowance for replacement of existing radiators with larger low temperature radiators where necessary, but do not allow for extensive re-piping of services or internal making good.

Photovoltaics have been sized and costed to achieve EPC band A only and assume that a suitably orientated roof is available. The size of the PV array could potentially be increased and the cost would increase on a pro rata basis. For calculation purposes, in flat archetypes an assumption has been made that the block roof can be utilised. This may not be practical from a building or landlord's perspective.

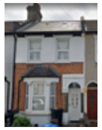
The costs provided are indicative only and cannot be relied upon. The base date for these costs is June 2022.

Figure 47 Location factor table

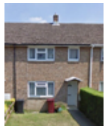
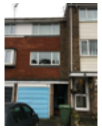
Location factor*	Multiplier
Default location	1.00
London	1.24
South East	1.08
South West	1.02
East Midlands	1.05
West Midlands	0.96
North East	0.93
North West	0.97

* Location factor (information taken from the BCIS) - the extra over costs are set at the 'default location' rate. Multiply the selected cost by the required location factor.

Archetypes summary table

Archetype Number	Photo	Assessed date of construction	Description	Area (m2)	Current EPC banding	Current SAP	Link
1a		Circa 1850	Ground floor villa flat conversion, solid wall	48	C	71	View here
1b		Circa 1850	Mid floor villa flat conversion, solid wall	48	C	75	View here
1c		Circa 1850	Top floor villa flat conversion, solid wall	48	C	71	View here
2		Pre-1900	Terraced house, solid wall (EWI front and rear)	97.7	D	64	View here
2a		Pre-1900	Terraced house, solid wall (IWI front and EWI rear)	97.7	D	64	View here
3a		1930-1949	Ground floor flat, cavity wall	31.7	D	68	View here
3b		1930-1949	Top floor flat, cavity wall	31.7	C	70	View here
4		1930-1949	Semi-detached house, cavity wall	69.5	D	64	View here

Archetype Number	Photo	Assessed date of construction	Description	Area (m2)	Current EPC banding	Current SAP	Link
5a		1950-1966	Ground floor flat, cavity wall	80.5	D	66	View here
5b		1950-1966	First floor flat, cavity wall	80.5	D	67	View here
6		1950-1966	Semi detached system built house (Unity)	84	D	61	View here
7a		1950-1966	Ground floor flat system build (Wimpey no-fines)	78.87	C	70	View here
7b		1950-1966	Mid floor flat system build (Wimpey no-fines)	78.87	C	74	View here
7c		1950-1966	Top floor flat system build (Wimpey no-fines)	78.87	C	70	View here
8a		1950-1966	End of terrace house, solid wall	65.6	D	58	View here
8b		1950-1966	Mid-terrace house, solid wall	67	D	65	View here
9		1950-1966	Detached bungalow, cavity wall	40.6	D	66	View here

Archetype Number	Photo	Assessed date of construction	Description	Area (m2)	Current EPC banding	Current SAP	Link
10		1966-1975	Mid-terrace house, cavity wall	88.3	D	67	View here
11a		1966-1975	Ground floor flat, cavity wall	48.4	D	66	View here
11b		1966-1975	Mid floor flat, cavity wall	48.4	C	71	View here
11c		1966-1975	Top floor flat, cavity wall	48.4	D	67	View here
12		1966-1975	Mid Terrace town house, cavity wall	96	C	72	View here
13a		1966-1975	Ground floor flat, cavity wall	78.87	D	66	View here
13b		1966-1975	Mid floor flat, cavity wall	78.87	C	70	View here
13c		1966-1975	Top floor flat, cavity wall	78.87	D	65	View here
14		1976-1982	Upper maisonette, cavity and panel wall	78.0	D	66	View here

SOME FINAL THOUGHTS

As can be seen from the archetype tables, achieving EPC band C in many archetypes is relatively straight forward. However, the work required to take significant steps towards a nearly zero carbon home and move though EPC band C into EPC band B is significant. However, through this transition, the space heating demand drops by more than half in houses and more in flats.

In some cases, the introduction of CMEV and MVHR initially tends to have a negative effect on the SAP score as auxiliary energy is being introduced to power the fans in the ventilation systems. In same cases where the home is at the lowest end of the EPC banding, the introduction of mechanical ventilation systems even drops the EPC banding. However, the space heating demand continues to drop.

Our experience is that CMEV is less disruptive for residents and takes less space as the unit is smaller and there is less ducting, hence its selection for flats. However, from the point of its selection, MVHR will produce similar or marginally better SAP scores but always lower space heating demand. Once a low carbon heat source is introduced this gap opens up and stays consistent.

It is clear that, in many cases, a significant impact can be made upon EPC bandings, SAP ratings and, more importantly for residents, space heating demand and fuel bills, by following a fabric first approach with a ventilation package. When carried out within a PAS 2035 compliant strategic asset management programme with medium term improvement plans, this may enable better value low carbon heat and potentially new technologies to be introduced later. Whatever strategy is adopted across a portfolio, it must achieve the highest possible carbon reduction in the shortest possible time.

The fabric values and servicing options selected mean EPC B ratings can be achieved without PV but PV will assist with residents' fuel costs particularly in combination with smart energy storage solutions. In multi residential blocks the roof to total floor area ratio is such that PV allocation to each unit will be very low. However, as can been seen from the archetype tables, mid floor units can achieve extremely low space heating demand levels meaning the higher costs of retrofitting multi residential blocks can achieve some dramatic reductions in heating costs.

In considering whole life carbon, and particularly short term emissions, some emerging thinking is suggesting that if a low carbon heat source, such as an air source heat pump, is introduced, the embodied carbon of some fabric first measures (e.g. triple glazed windows) may never be recouped via better performance since the additional heat lost, via a less efficient product, is so low carbon. Detailed analysis of this area will require the use of product databases of embodied carbon which will change over time as industries decarbonise. An article on this emerging subject can be found **here**.

When considered as a cost per m^2 for the total retrofit works package, a very wide variance is seen ranging between circa £780 and £1930 per m^2. The key issue is the **form factor** where an archetype has a higher ratio of heat loss elements e.g. floors, walls and roof, compared to its usable floor area. As can be seen in archetype 7 (a bungalow) achieving a net zero ready retrofit is prohibitively expensive compared to other archetypes. This should be taken into consideration in your organisation's strategy.

The revised toolkit is intended as a guide only, but Baily Garner will be taking data from our ongoing retrofit projects to update the information presented and to produce new information to continue to develop a library of archetypes as used in the toolkit.

Our experience from our ongoing projects is that Net Zero Carbon ready homes, following a 'fabric first, lowest regrets' approach, can be achieved with lower performance values than used in this toolkit. Such a relaxation requires very careful consideration but may enable organisations to reduce construction costs at junctions and alleviate fuel poverty for more residents within a Strategic Asset Management Strategy.

We are all facing a climate and ecological emergency and the time to act is now. Retrofitting our old and poorly performing existing homes will help residents and is a crucial part of reaching net zero as soon as possible. However, it is difficult and expensive. This toolkit should assist organisations to shape their strategy and take practical steps to start retrofitting their existing stock now.

For further information on how Baily Garner can help you with retrofitting your existing homes, contact us.

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APPENDIX 1 - GLOSSARY

Air tightness - a general descriptive term for the resistance of the building envelope to infiltration with ventilators closed. The greater the airtightness at a given pressure difference across the envelope, the lower the infiltration.

Biodiversity loss - the decline or disappearance of biological diversity, understood as the variety of living things that inhabit the planet, its different levels of biological organisation and their respective genetic variability, as well as the natural patterns present in ecosystems.

Building renovation passports - digital tools to help property owners access decision-useful information to retrofit their home. They provide information on the current energy performance of a property and past renovations. They are underpinned by a long-term retrofit roadmap (MTIP) that identifies future decarbonisation measures, along with links to contractors and finance options.

Circular economy – An economy based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.

Clean Growth Strategy – Published on 12 October 2017 by the Department for Business, Energy & Industrial Strategy (DBEIS) and described as; 'An ambitious strategy setting out how the UK is leading the world in cutting carbon emissions to combat climate change while driving economic growth'.

Deep retrofit - A whole-building holistic process making use of existing technologies, materials and construction practices to achieve significant reductions in energy usage.

Embodied carbon - The carbon emissions associated with the extraction and processing of materials and the energy and water consumption used by the factory in producing products and constructing the building. It also includes the 'in-use' stage (maintenance, replacement, and emissions associated with refrigerant leakage) and 'end of life' stage (demolition, disassembly, and disposal of any parts of product or building) and any transportation relating to the above.

Emissions – A general term encompassing total greenhouse gas emissions, the principal gas being carbon dioxide.

Energiesprong - Energiesprong was created by the government of the Netherlands in 2010 to retrofit existing buildings for higher energy efficiency standards to become near zero-energy buildings

English Housing Survey - a continuous national survey commissioned by the Ministry of Housing, Communities and Local Government (MHCLG), now the Department for Levelling Up, Housing and Communities (DLUHC). It collects information about people's housing circumstances and the condition and energy efficiency of housing in England.

ESG - Environmental, Social, and Governance factors are non-financial factors being applied by investors as part of their analysis process to identify material risks and growth opportunities.

Form factor - The ratio of heated floor space to heat loss envelope (ground, walls, and roof).

Fuel poverty - a term used to identify households that are pushed into poverty because of the amount they spend on fuel.

Future Homes Standard – A standard to improve the energy performance of new homes, with homes being highly energy efficient, with low carbon heating and zero carbon ready by 2025. These homes are expected to produce 75-80% lower carbon emissions compared to current levels.

G-values – The total solar gain divided by the incident solar radiation. A value of 1 = the maximum possible solar gain and 0 = no solar gain. Typical solar control glazing will have a value of 0.5.

Heat and Buildings Strategy – Published on 19 October 2021 by the Department for Business, Energy & Industrial Strategy (DBEIS) the strategy sets out how the UK will decarbonise our 30 million homes, commercial, industrial and public sector buildings, as part of setting a path to net zero by 2050.

Lowest regrets – the approach taken to a retrofit should minimise the potential of measures installed having to be replaced in the future journey to net zero.

Medium-term improvement plan (MTIP) – A property bespoke plan required under PAS 2035 for any dwelling that is proposed for retrofit, consideration should be given to the scope for improving energy efficiency and reducing emissions. The overall scope for improvement by 2050 should be identified, even if only limited improvements can be undertaken in the short term.

Net Present Value (NPV) – The present day value of future costs, net of future incomes.

Net zero – a generic term meaning that the UK's total greenhouse gas (GHG) emissions would be equal to or less than the emissions the UK removed from the environment achieved by a combination of emission reduction and emission removal.

Net Zero Strategy: Build Back Greener - Published on 19 October 2021 by the UK Government, the strategy sets out how the government intends to achieve Net Zero by 2050

Operational carbon - The carbon dioxide and equivalent global warming potential (GWP) of other gases associated with the in-use operation of the building. This usually includes carbon emissions associated with heating, hot water, cooling, ventilation, and lighting systems, as well as those associated with cooking, equipment, and lifts (i.e. both regulated and unregulated energy uses)

PAS - Publicly Available Specification

Passivhaus - An energy performance standard for dwellings, commercial, industrial and public buildings adopting principles of passive design.

Passivhaus Planning Package (PHPP) – An excel based planning tool to undertake energy efficiency calculations to accurately predict a building's heating, cooling and primary energy demand.

Performance gap - The difference between anticipated, through design calculation, and actual in-use energy performance of a building.

Renewable energy - energy derived from sources which are naturally replenished or are practically inexhaustible.

Shallow internal retrofit – The installation of energy efficiency measure such as internal wall insulation and building services only affecting the internal aspects of a home.

Smart cylinder - A hot water cylinder able to utilise renewable energy produced on site, operate with dynamic energy tariffs and act as energy storage device to reduce overall energy costs.

Social Value - The net measure of total welfare resulting from an option or intervention.

Soft landings - The process of aligning the interests of those who design and construct an asset with the interests of those who use and manage

Thermal mass - The ability of a material to absorb, store and release heat energy

TrustMark - A government-endorsed scheme for trusted tradesmen and professionals in the domestic sector

Upfront carbon - The carbon emissions associated with the extraction and processing of materials, the energy and water consumption used by the factory in producing products, transporting materials to site, and constructing the building

Voids - a property which is vacant between tenancies

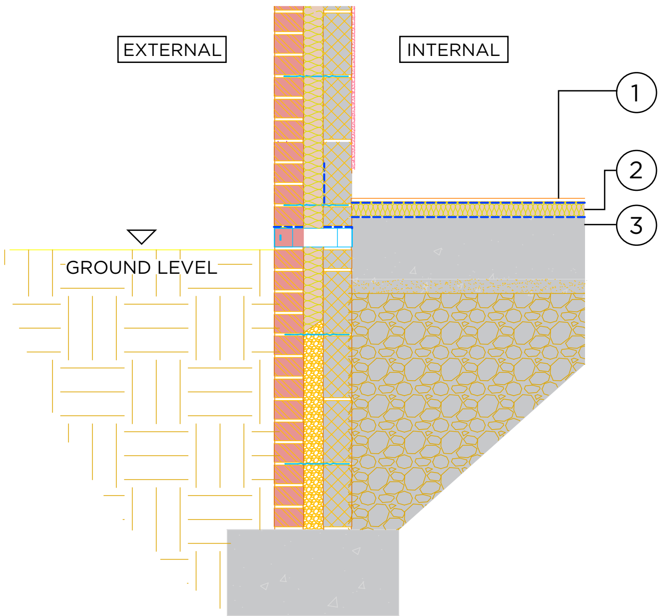
Whole life carbon - Embodied carbon and operational carbon. The purpose of using whole life carbon is to move towards a building or a product that generates the lowest possible carbon emissions over its whole life (sometimes referred as 'cradle-to-grave').

Whole Life Cost - The total cost of ownership over the life of an asset (assumed in this toolkit at 60 years) based upon net present value methodology.

APPENDIX 2 - ELEMENT AND COMPONENT BUILD UPS AND DETAILS

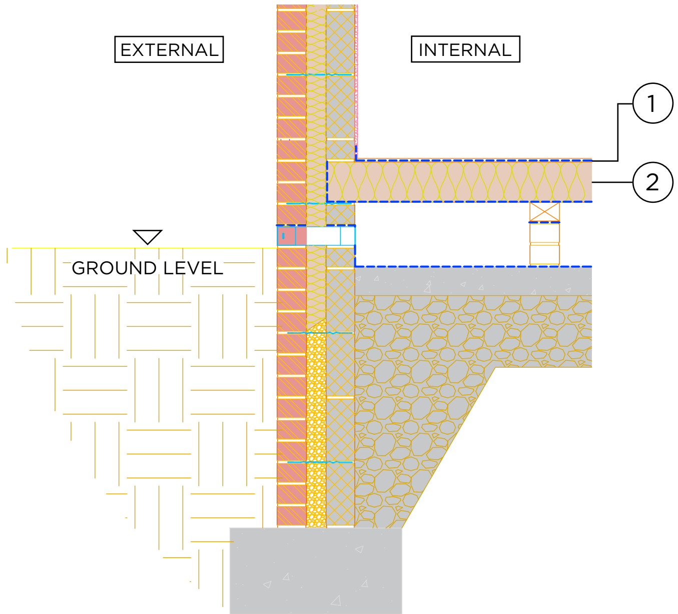
FLOORS

Retained Solid Floor



1. Floating board finish
2. 50mm XPS Insulation Board
3. DPM if any sign of dampness on the floor

Suspended Timber Floor



1. Vapour control layer and air tightness membrane
2. 300mm mineral wool insulation between joists (insulation should be airtight but if not then apply breather membrane to underside)

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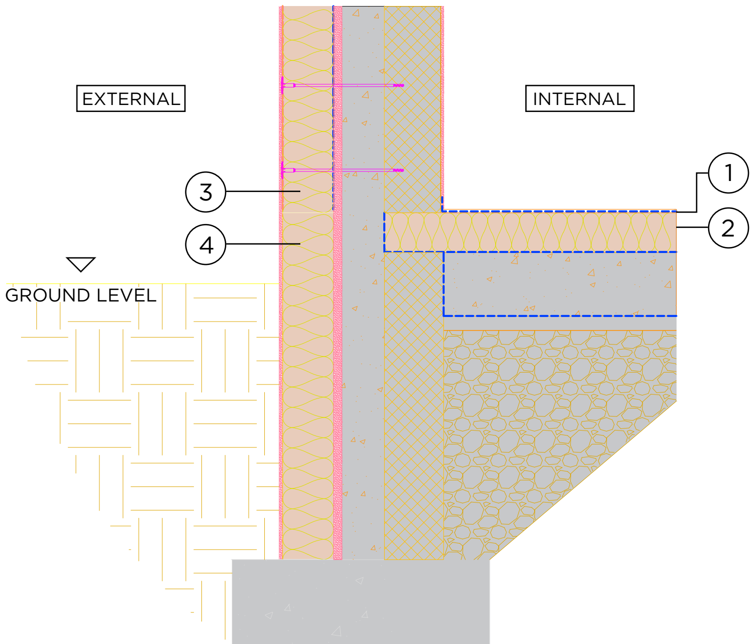
APPENDIX 2 - ELEMENT AND COMPONENT BUILD UPS AND DETAILS

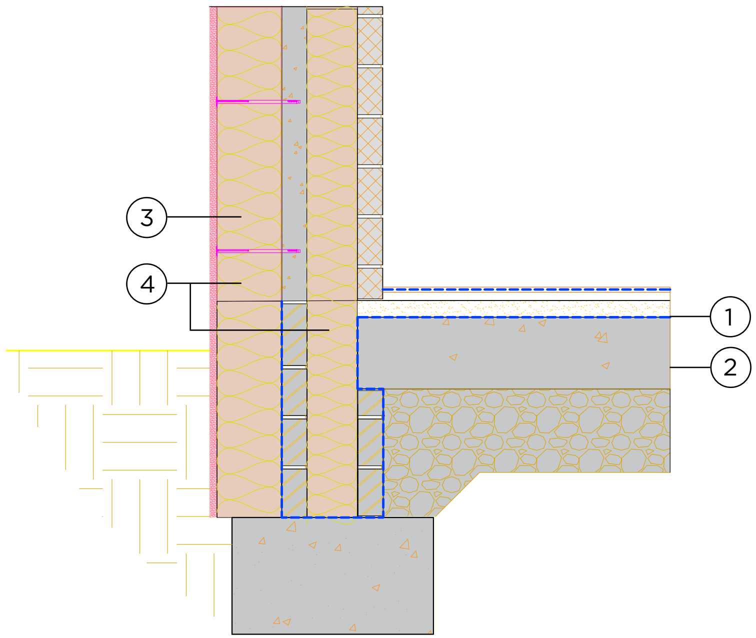
FLOORS

Retained Solid Floor



1. Vapour control layer and air tightness membrane
2. 140mm mineral wool insulation between joists (insulation should be airtight but if not then apply breather membrane to underside)
3. 200mm External Wall Insulation (EWI)
4. 200mm EPS insulation

Retained Solid Floor



1. Vapour control layer and air tightness membrane
2. 215mm Solid Concrete Construction
3. 200mm External Wall Insulation (EWI)
4. EPS insulation

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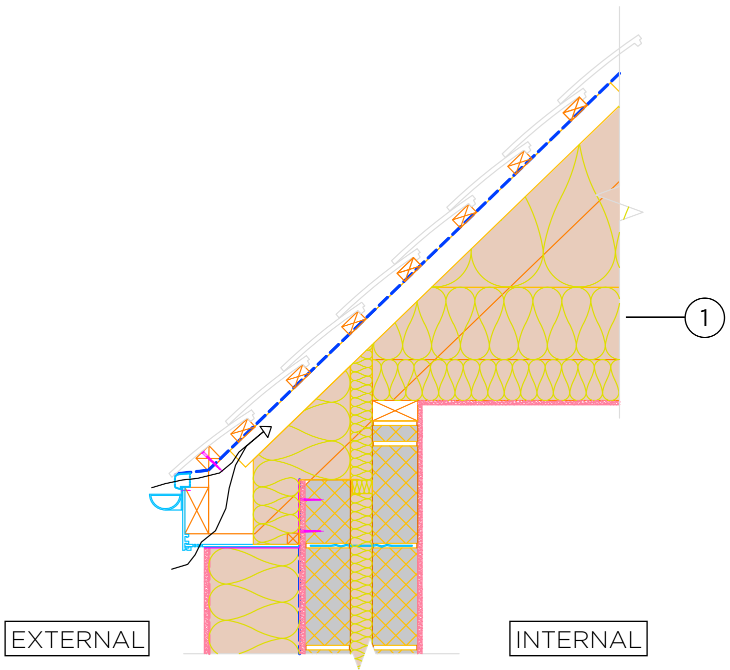
APPENDIX 2 - ELEMENT AND COMPONENT BUILD UPS AND DETAILS

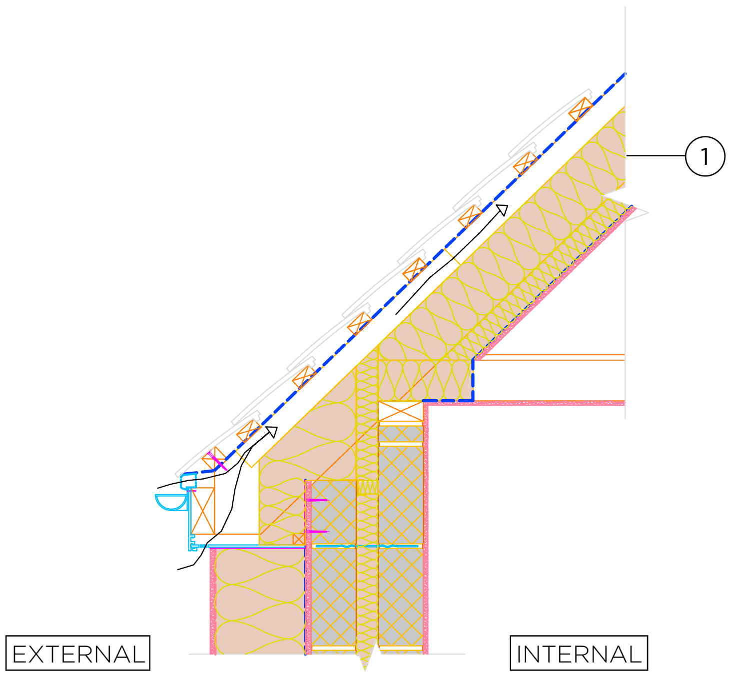
ROOFS

Roof Insulated Between and Above Ceiling Joists



1. 400mm additional Mineral Wool Slab Insulation

Roof Insulated Between and Below Rafters



1. Additional Mineral Wool Slab Insulation

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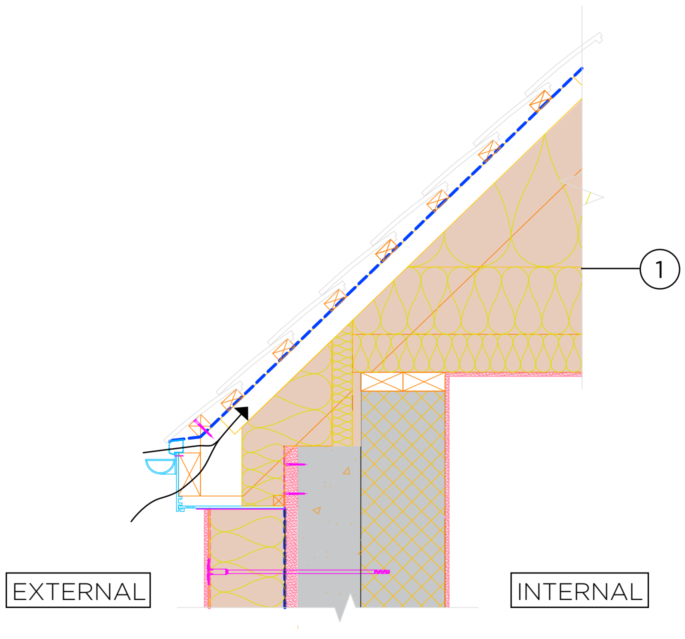
APPENDIX 2 - ELEMENT AND COMPONENT BUILD UPS AND DETAILS

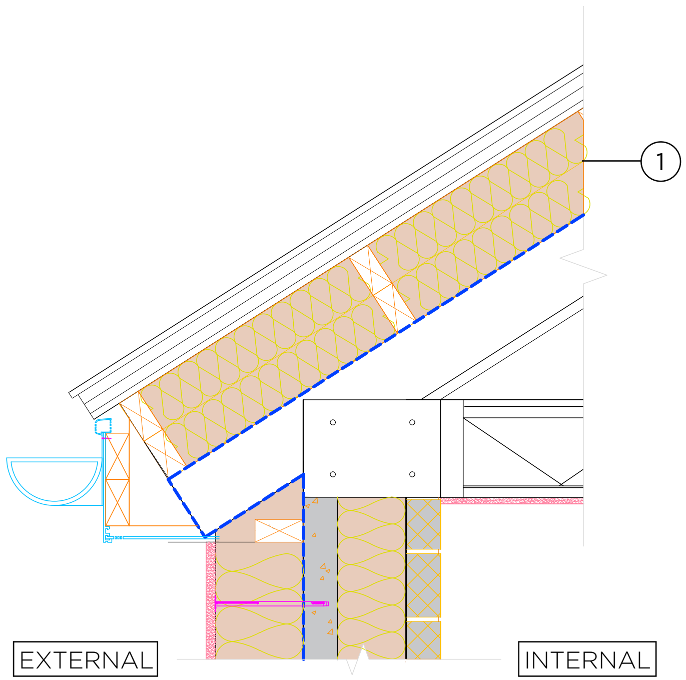
ROOFS

Roof Insulated Between and Above Ceiling Joists



1. 400mm additional Mineral Wool Slab Insulation

Roof Insulated Between Rafters



1. Additional Mineral Wool Slab Insulation

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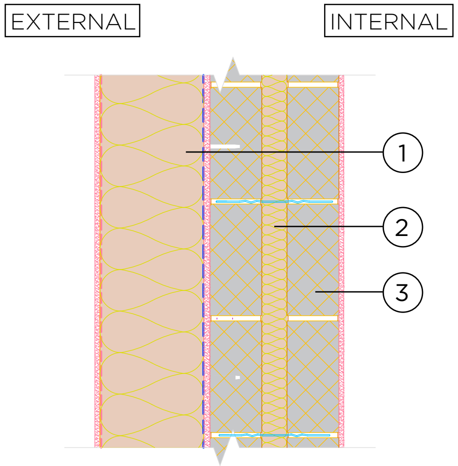
APPENDIX 2 - ELEMENT AND COMPONENT BUILD UPS AND DETAILS

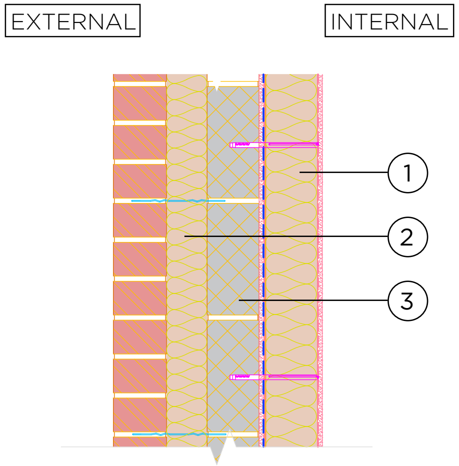
WALLS

External Wall Insulation on Existing Cavity Wall



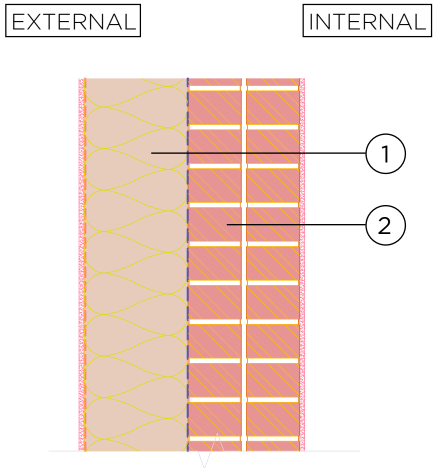
1. 150mm External Wall Insulation (EWI)
2. Cavity Fill Insulation
3. Existing Cavity Wall

Internal Wall Insulation on Existing Cavity Wall



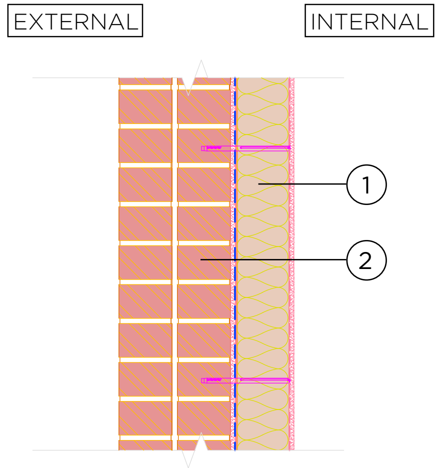
1. 75mm Internal Wall Insulation (IWI)
2. Cavity Fill Insulation
3. Existing Cavity Wall

External Wall Insulation on Existing Solid Wall



1. 150mm External Wall Insulation (EWI)
2. Existing Solid Wall

Internal Wall Insulation on Existing Solid Wall



1. 75mm Internal Wall Insulation (IWI)
2. Existing Solid Wall

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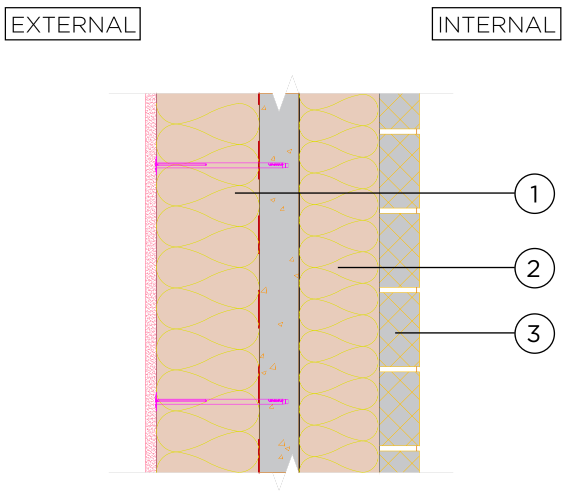
APPENDIX 2 - ELEMENT AND COMPONENT BUILD UPS AND DETAILS

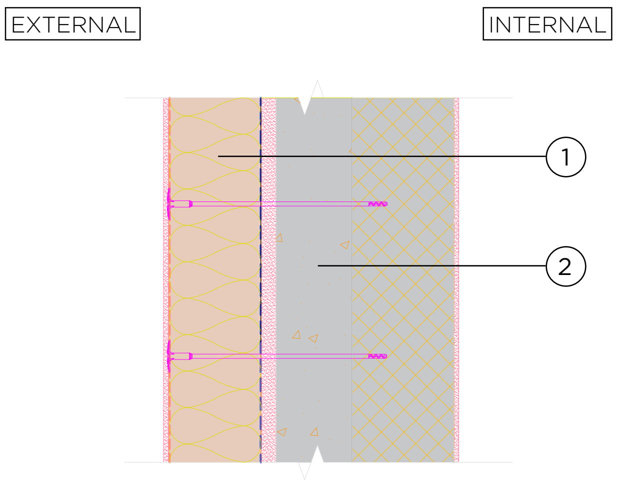
WALLS

External Wall Insulation on Existing Cavity Wall



1. 200mm External Wall Insulation (EWI)
2. Cavity Fill Insulation
3. Existing Cavity Wall

External Wall Insulation on Existing Solid Wall



1. 180mm External Wall Insulation (EWI)
2. Existing Solid Wall

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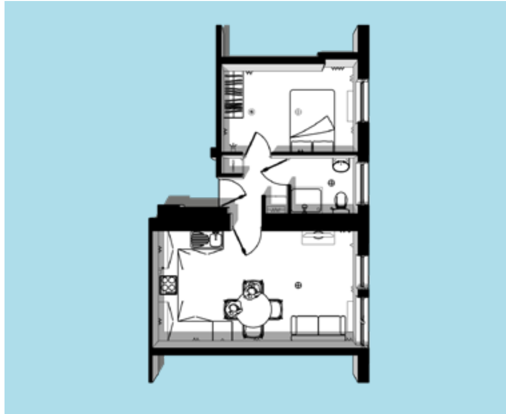
APPENDIX 3 - ARCHETYPE TABLES

Archetype 1a Circa 1850 ground floor villa flat conversion, solid wall - 48m^2

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m^2/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**C (71)**	119.6 (131.5)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	**2. Replace existing cavity fill insulation**			N/A	N/A	£0.00	£0.00	£0.00	£0.00
Fabric First Approach	**3. 150mm EWI**			**C (71)**	117.3 (129)	£7,194.40	£7,194.40	£9,463.80	£7,985.78
Fabric First Approach	**4. Double glazing**			**C (74)**	95 (104.5)	£1,512.88	£8,707.28	£11,453.90	£1,679.29
Fabric First Approach	**5. Air tightness measures**			**C (77)**	75.7 (83.3)	£1,300.00	£10,007.28	£13,163.97	
Fabric First Approach	**6. Thermal Bridging calculations**			**C (79)**	59 (64.9)	£1,000.00	£11,007.28	£14,479.41	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£4,347.00	£15,354.28	£20,197.63	£4,912.11
HVAC		**Results**	**EPC rating**	**C (80)**	**C (80)**				
HVAC		**Results**	**Energy demand kWh/m^2/yr**	59 (64.9)	51.4 (56.6)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£9,723.04	£25,077.32	£32,987.71	£11,249.56
HVAC		**Results**	**EPC rating**	**B (82)**	**B (84)**				
HVAC		**Results**	**Energy demand kWh/m^2/yr**	60.6 (66.6)	52.8 (58.1)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£6,753.78	£31,831.10	£41,871.90	£ 7,631.77
Further Fabric		**Results**	**EPC rating**	**B (89)**	**B (91)**				
Further Fabric		**Results**	**Energy demand kWh/m^2/yr**	36.6 (40.2)	28.7 (31.5)				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£776.25	£32,607.35	£42.893.01	£894.24
Renewable Technology		**Results**	**EPC rating**	**A (97)**	**A (98)**				
Renewable Technology		**Results**	**kWp**	0.4	0.2				
Renewable Technology		**Results**	**Energy demand kWh/m^2/yr**	36.6 (40.2)	28.7 (31.5)				

Contingency @ 5%	£1,630.37	£34,237.72
Subtotal		**£34,237.72**
Prelims @ 16%	£5,478.03	£39,715.75
OH&P @ 8%	£3,177.26	£42,893.01
Total £		**£42,893.01**



Notes

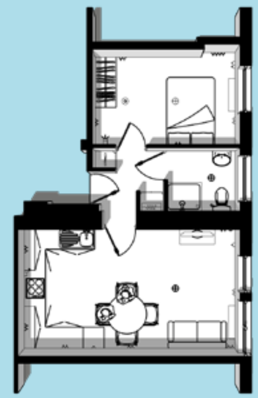
This period building is a live case study. Energy modelling shows the theoretical pathway to EPC A and low heat demand. However, it is unlikely that space will be available for individual ASHP condensor units or internal cylinder storage. In some circumstances building services options in figures 43 and 45 may be applicable. Planning may require brick slip finishes to EWI at circa £5K per unit. A more likely practical outcome for this type of converted mansion block is a combination of EWI/IWI, replacement window/secondary glazing, improved airtightness, Improved decentralised ventilation, high efficiency electric heating and unobtrusive PV. This ground floor unit has disadvantages and earlier inclusion of floor insulation may be warranted.

Back to archetypes summary

Archetype 1b Circa 1850 mid floor villa flat conversion, solid wall - 48m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**C (75)**	93.7 (103)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	**2. Replace existing cavity fill insulation**			N/A	N/A	£0.00	£0.00	£0.00	£0.00
Fabric First Approach	**3. 150mm EWI**			**C (78)**	70.2 (77.2)	£7,194.40	£7,194.40	£9,463.80	£7,985.78
Fabric First Approach	**4. Double glazing**			**B (82)**	43.5 (47.8)	£1,512.88	£8,707.28	£11,453.90	£1,679.29
Fabric First Approach	**5. Air tightness measures**			**B (84)**	21.5 (23.7)	£1,300.00	£10,007.28	£13,163.97	
Fabric First Approach	**6. Thermal Bridging calculations**			**B (85)**	16 (17.6)	£1,000.00	£11,007.28	£14,479.41	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£4,347.00	£15,354.28	£20,197.63	£4,912.11
		Results	EPC rating	**B (85)**	**B (85)**				
			Energy demand kWh/m²/yr	16 (17.6)	9.2 (10.1)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£9,723.04	£25,077.32	£32,987.71	£11,249.56
		Results	EPC rating	**A (95)**	**A (95)**				
			Energy demand kWh/m²/yr	16.9 (18.6)	9.9 (10.9)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£0.00	£25,077.32	£32,987.71	£0.00
		Results	EPC rating	N/A	N/A				
			Energy demand kWh/m²/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£0.00	£25,077.32	£32,987.71	£0.00
		Results	EPC rating	**A (98)**	**A (98)**				
			kWp	0.0	0.0				
			Energy demand kWh/m²/yr	16.9 (18.6)	9.9 (10.9)				

Contingency @ 5%	£1,253.87	£26,331.19
Subtotal		**£26,331.19**
Prelims @ 16%	£4,212.99	£30,544.17
OH&P @ 8%	£2,443.53	£32,987.71
Total £		**£32,987.71**



Notes

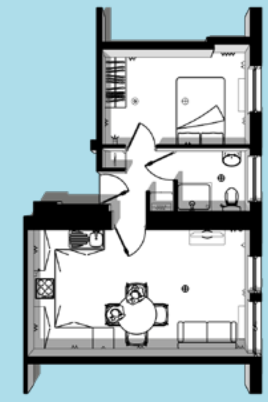
This period building is a live case study. Energy modelling shows the theoretical pathway to EPC A and low heat demand. However, it is unlikely that space will be available for individual ASHP condensor units or internal cylinder storage. In some circumstances building services options in figures 43 and 45 may be applicable. Planning may require brick slip finishes to EWI at circa £5,000 per unit. A more likely practical outcome for this type of converted mansion block is a combination of EWI/IWI, replacement window/secondary glazing, improved airtightness, Improved decentralised ventilation, high efficiency electric heating and unobtrusive PV.

Back to archetypes summary

Archetype 1c Circa 1850 top floor villa flat conversion, solid wall - 48m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**C (71)**	121.9 (134.1)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			**C (73)**	107.9 (118.6)	£1,702.85		£2,240.00	£1,890.16
Fabric First Approach	**2. Replace existing cavity fill insulation**			N/A	N/A	£0.00	£1,702.85	£2,240.00	£0.00
Fabric First Approach	**3. 150mm EWI**			**C (76)**	85.4 (93.9)	£7,507.20	£9,210.05	£12,115.27	£8,332.99
Fabric First Approach	**4. Double glazing**			**C (79)**	60.1 (66.2)	£1,870.53	£11,080.58	£14,575.84	£2,076.29
Fabric First Approach	**5. Air tightness measures**			**B (82)**	38.7 (42.6)	£1,300.00	£12,380.58	£16,285.91	
Fabric First Approach	**6. Thermal Bridging calculations**			**B (84)**	20.7 (22.8)	£1,000.00	£13,380.58	£17,601.35	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£4,347.00	£17,727.58	£23,319.57	£4,912.11
HVAC		Results	EPC rating	**B (85)**	**B (85)**				
HVAC		Results	Energy demand kWh/m²/yr	20.7 (22.8)	13.4 (14.8)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£9,723.04	£27,450.62	£36,109.65	£11,249.56
HVAC		Results	EPC rating	**A (93)**	**A (94)**				
HVAC		Results	Energy demand kWh/m²/yr	21.7 (23.8)	14.3 (15.7)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£0.00	£27,450.62	£36,109.65	£0.00
Further Fabric		Results	EPC rating	N/A	N/A				
Further Fabric		Results	Energy demand kWh/m²/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£0.00	£27,450.62	£36,109.65	£0.00
Renewable Technology		Results	EPC rating	**A (93)**	**A (94)**				
Renewable Technology		Results	kWp	0.0	0.0				
Renewable Technology		Results	Energy demand kWh/m²/yr	21.7 (23.8)	14.3 (15.7)				

Contingency @ 5%	£1,372.53	£28,823.16
Subtotal		**£28,823.16**
Prelims @ 16%	£4,611.70	£33,434.86
OH&P @ 8%	£2,674.79	£36,109.65
Total £		**£36,109.65**



Notes

This period building is a live case study. Energy modelling shows the theoretical pathway to EPC A and low heat demand. However, it is unlikely that space will be available for individual ASHP condensor units or internal cylinder storage. In some circumstances building services options in figures 43 and 45 may be applicable. Planning may require brick slip finishes to EWI at circa £5,000 per unit. A more likely practical outcome for this type of converted mansion block is a combination of EWI/IWI, replacement window/secondary glazing, improved airtightness, Improved decentralised ventilation, high efficiency electric heating and unobtrusive PV.

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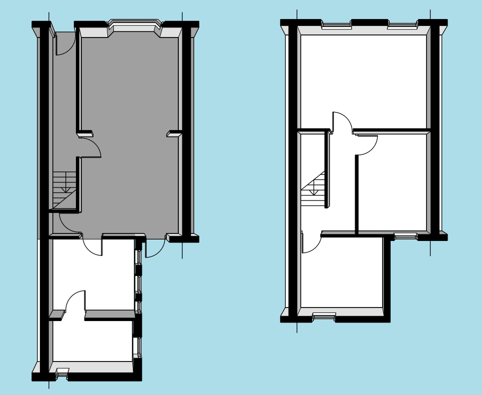
Archetype 2 Pre 1900 terraced house, solid wall - 97.7m²

	Upgrades		Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing		**D (64)**	149.1 (164)				
Fabric First Approach	**1. Top up roof insulation to 400mm**		**D (65)**	143.4 (157.8)	£1,884.09		£2,478.40	£2,091.34
Fabric First Approach	**2. Replace existing cavity fill insulation**		N/A	N/A	£0.00	£1,884.09	£2,478.40	£0.00
Fabric First Approach	**3. 150mm EWI only**		**C (74)**	95.6 (105.1)	£27,030.14	£28,914.23	£38,034.94	£30,003.46
Fabric First Approach	**4. Double glazing**		**C (76)**	88.7 (97.6)	£4,442.06	£33,356.29	£43,878.20	£4,930.69
Fabric First Approach	**5. Air tightness measures**		**C (78)**	74.9 (82.4)	£1,300.00	£34,656.29	£45,588.27	
Fabric First Approach	**6. Thermal Bridging calculations**		**B (82)**	54.7 (60.2)	£1,000.00	£35,656.29	£46,903.71	
HVAC	**7. Ventilation**	**Upgrades**	**CMEV**	**MVHR**	£6,244.11	£41,900.41	£55,117.47	£7,055.85
HVAC		Results: EPC rating	**B (82)**	**B (82)**				
HVAC		Results: Energy demand kWh/m²/yr	52.3 (57.5)	43.4 (47.8)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**	**ASHP**	**ASHP**	£12,197.04	£54,097.44	£71,161.94	£14,111.97
HVAC		Results: EPC rating	**B (82)**	**B (83)**				
HVAC		Results: Energy demand kWh/m²/yr	51.2 (56.3)	42.7 (47)				
Further Fabric	**9. Floor Insulation**	**Upgrades**	**Floor insulation**	**Floor insulation**	£6,874.79	£60,972.23	£80,205.31	£7,768.51
Further Fabric		Results: EPC rating	**B (85)**	**B (85)**				
Further Fabric		Results: Energy demand kWh/m²/yr	38.9 (42.8)	30 (33)				
Renewable Technology	**10. Photovoltaics**	**Upgrades**	**PV**	**PV**	£5,433.75	£66,405.98	£87,353.08	£6,259.68
Renewable Technology		Results: EPC rating	**A (93)**	**A (93)**				
Renewable Technology		Results: kWp	2.2	2.0				
Renewable Technology		Results: Energy demand kWh/m²/yr	30 (33)	30 (33)				

Contingency @ 5%	£3,320.30	£69,726.28
Subtotal		**£69,726.28**
Prelims @ 16%	£11,156.20	£80,882.48
OH&P @ 8%	£6,470.60	£87,353.08
Total £		**£87,353.08**

Notes

This variation of EWI only is for areas where planning may allow it. No cost allowance for a brick slip finish has been made which would be circa £10,000. Below DPC EWI may be required (to avoid PAS non-compliance) not included, suggest circa £5,000. Full air pressure testing and careful remedial works will be required to reduce airtightness down to 5. Floor insulation is 1/3 solid and 2/3 suspended timber - dependent on site conditions insulation sprayed from floor void may be possible.



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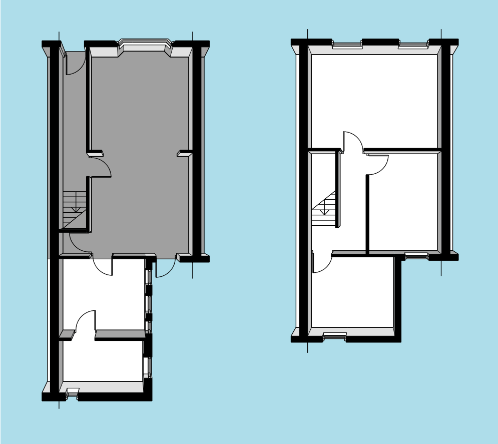
Archetype 2a Pre 1900 terraced house, solid wall - 97.7m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**D (64)**	149.1 (164)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			**D (64)**	143.4 (157.7)	£1,884.09		£2,478.40	£2,091.34
Fabric First Approach	**2. Replace existing cavity fill insulation**			N/A	N/A	£0.00	£1,884.09	£2,478.40	£0.00
Fabric First Approach	**3. 150mm EWI & 75mm IWI**			**C (74)**	101.3 (111.4)	£23,957.82	£25,841.91	£33,993.48	£26,593.18
Fabric First Approach	**4. Double glazing**			**C (76)**	94.6 (104.1)	£4,434.91	£30,276.82	£39,827.34	£4,922.75
Fabric First Approach	**5. Air tightness measures**			**C (78)**	81.1 (89.2)	£1,300.00	£31,576.82	£41,537.41	
Fabric First Approach	**6. Thermal Bridging calculations**			**B (82)**	61.5 (67.6)	£1,000.00	£32,576.82	£42,852.85	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£6,244.11	£38,820.93	£51,066.61	£7,055.85
HVAC		Results	EPC rating	**B (81)**	**B (81)**				
HVAC		Results	Energy demand kWh/m²/yr	59.1 (65.0)	48.0 (52.8)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£12,197.04	£51,017.97	£67,111.08	£14,111.97
HVAC		Results	EPC rating	**B (81)**	**B (81)**				
HVAC		Results	Energy demand kWh/m²/yr	57.6 (63.4)	47.1 (51.8)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£6,874.79	£57,892.75	£76,154.44	£7,768.51
Further Fabric		Results	EPC rating	**B (83)**	**B (84)**				
Further Fabric		Results	Energy demand kWh/m²/yr	45.7 (50.3)	34.6 (38.0)				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£5,433.75	£63,326.50	£83,302.22	£6,259.68
Renewable Technology		Results	EPC rating	**A (93)**	**A (93)**				
Renewable Technology		Results	kWp	2.2	2.0				
Renewable Technology		Results	Energy demand kWh/m²/yr	45.7 (50.3)	34.6 (38.0)				

Contingency @ 5%	£3,166.33	£66,492.83
Subtotal		**£66,492.83**
Prelims @ 16%	£10,638.85	£77,131.68
OH&P @ 8%	£6,170.53	£83,302.22
Total £		**£83,302.22**

Notes

In this IWI to front elevation will require careful detailing to avoid thermal bridges. Below DPC EWI at rear may be required (to avoid PAS non-compliance) not included, suggest circa £3,000. Full air pressure testing and careful remedial works will be required to reduce airtightness down to 5. Floor insulation is 1/3 solid and 2/3 suspended timber - dependent on site conditions insulation sprayed from floor void may be possible.



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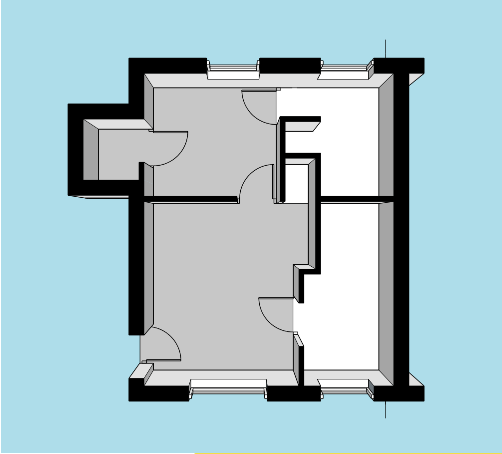
Archetype 3a 1930-1949 ground floor flat, cavity wall - 31.7m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			C (70)	144.4 (158.8)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	**2. Replace existing cavity fill insulation**			C (72)	124.6 (137)	£2,159.33	£2,159.33	£2,840.47	£2,396.86
Fabric First Approach	**3. 150mm EWI**			C (74)	112 (123.2)	£9,915.76	£12,075.09	£15,884.06	£11,006.49
Fabric First Approach	**4. Double glazing**			C (75)	102.3 (112.6)	£2,657.37	£14,732.46	£19,379.67	£2,949.68
Fabric First Approach	**5. Air tightness measures**			C (77)	86.8 (95.5)	£1,300.00	£16,032.46	£21,089.74	
Fabric First Approach	**6. Thermal Bridging calculations**			C (79)	64.9 (71.4)	£1,000.00	£17,032.46	£22,405.18	
HVAC	**7. Ventilation**	Upgrades		CMEV	MVHR	£4,234.53	£21,266.99	£27,975.45	£4,785.02
HVAC		Results	EPC rating	C (80)	C (80)				
HVAC		Results	Energy demand kWh/m²/yr	59.3 (65.2)	52.8 (58.1)				
HVAC	**8. Low Carbon Heat Source**	Upgrades		ASHP	ASHP	£9,220.46	£30,487.45	£40,104.41	£10,668.07
HVAC		Results	EPC rating	C (78)	C (79)				
HVAC		Results	Energy demand kWh/m²/yr	58.8 (64.6)	52.6 (57.8)				
Further Fabric	**9. Floor Insulation**	Upgrades		Floor insulation	Floor insulation	£2,230.15	£32,717.60	£43,038.04	£2,520.07
Further Fabric		Results	EPC rating	B (83)	B (84)				
Further Fabric		Results	Energy demand kWh/m²/yr	36.7 (40.4)	30.1 (33.1)				
Renewable Technology	**10. Photovoltaics**	Upgrades		PV	PV	£3,363.75	£36,081.35	£47,462.86	£3,875.04
Renewable Technology		Results	EPC rating	B (91)	A (93)				
Renewable Technology		Results	kWp	1.4	1.2				
Renewable Technology		Results	Energy demand kWh/m²/yr	36.7 (40.4)	30.1 (33.1)				



Notes

Below DPC EWI may be required to avoid PAS non-compliance not included, suggest circa £3,000. Meter box and cable relocation could present EWI programme and stats cordination difficulties. Location of ASHP condenser unit subject to space and planning constraints. Floor insulation is 1/3 solid and 2/3 suspended timber - dependent on site conditions insulation sprayed from floor void may be possible.

Contingency @ 5%	£1,804.07	£37,885.42
Subtotal		**£37,885.42**
Prelims @ 16%	£6,061.67	£43,947.09
OH&P @ 8%	£3,515.77	£47,462.86
Total £		**£47,462.86**

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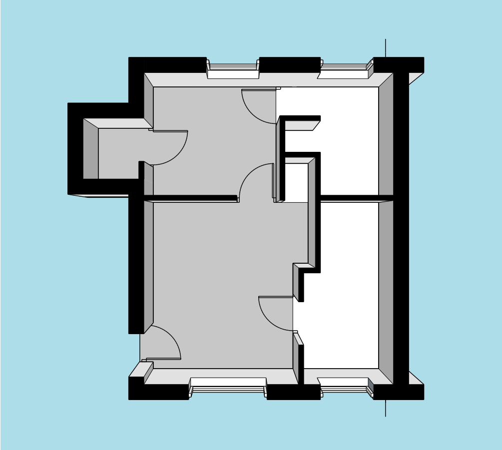
Archetype 3b 1930-1949 top floor flat, cavity wall - 31.7m^2

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m^2/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			C (72)	129.8 (142.8)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			C (73)	116.7 (128.3)	£1,222.38		£1,607.97	£1,356.84
	2. Replace existing cavity fill insulation			C (76)	94.8 (104.3)	£1,742.34	£2,964.72	£3,899.92	£1,934.00
	3. 150mm EWI			C (77)	80.8 (88.9)	£11,986.50	£14,951.22	£19,667.43	£13,305.01
	4. Double glazing			C (79)	69.4 (76.3)	£2,657.37	£17,608.59	£23,163.04	£2,949.68
	5. Air tightness measures			B (81)	52 (57.2)	£1,300.00	£18,908.59	£24,873.11	
	6. Thermal Bridging calculations			B (83)	27.7 (30.4)	£1,000.00	£19,908.59	£26,188.55	
HVAC	**7. Ventilation**	Upgrades		CMEV	MVHR	£4,234.53	£24,143.12	£31,758.82	£4,785.02
		Results	EPC rating	B (83)	B (83)				
			Energy demand kWh/m^2/yr	21.7 (23.8)	15.1 (16.7)				
	8. Low Carbon Heat Source	Upgrades		ASHP	ASHP	£9,220.46	£33,363.58	£43,887.78	£10,668.07
		Results	EPC rating	B (86)	B (88)				
			Energy demand kWh/m^2/yr	22.6 (24.8)	16.1 (17.8)				
Further Fabric	**9. Floor Insulation**	Upgrades		Floor insulation	Floor insulation	£0.00	£33,363.58	£43,887.78	£0.00
		Results	EPC rating	N/A	N/A				
			Energy demand kWh/m^2/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	Upgrades		PV	PV	£2,587.50	£35,951.08	£47,291.48	£2,980.80
		Results	EPC rating	A (92)	A (93)				
			kWp	1.0	0.8				
			Energy demand kWh/m^2/yr	22.6 (24.8)	16.1 (17.8)				

Contingency @ 5%	£1,797.55	£37,748.63
Subtotal		**£37,748.63**
Prelims @ 16%	£6,039.78	£43,788.41
OH&P @ 8%	£3,503.07	£47,291.48
Total £		**£47,291.48**



Notes

Low roof pitch may make installation of insulation, loft hatch adaptation, and air tightness measures difficult. Meter box and cable relocation could present EWI programme and stats cordination difficulties. Eaves depth/ roof may require adjustment to avoid PAS non-compliant detail/junction. Location of ASHP condenser unit subject to space and planning constraints.

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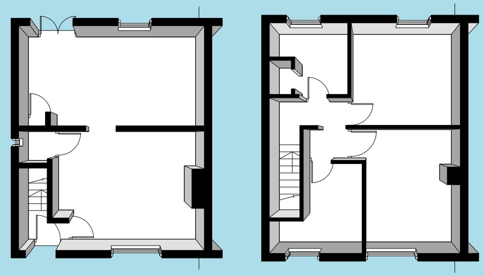
Archetype 4 1930-1949 semi-detached house, cavity wall - 69.5m^2

	Upgrades			Results		Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
				EPC rating (SAP score)	Space heating demand kWh/m^2/yr SAP (PHPP) values				
	Existing			D (64)	148.1 (162.9)				
Fabric First Approach	1. Top up roof insulation to 400mm			D (65)	142.2 (156.4)	£2,082.29	£6,100.05	£2,739.13	£2,311.34
Fabric First Approach	2. Replace existing cavity fill insulation			C (70)	118.7 (130.6)	£4,017.76	£40,812.40	£8,024.24	£4,459.71
Fabric First Approach	3. 150mm EWI			C (73)	102.7 (113)	£34,712.35	£45,386.79	£53,686.26	£38,530.71
Fabric First Approach	4. Double glazing			C (73)	99.4 (109.4)	£4,574.39	£46,686.79	£59,703.60	£5,077.58
Fabric First Approach	5. Air tightness measures			C (76)	87.5 (96.2)	£1,300.00	£47,686.79	£61,413.67	
Fabric First Approach	6. Thermal Bridging calculations			B (81)	61.3 (67.5)	£1,000.00	£36,785.98	£62,729.11	
HVAC	7. Ventilation	Upgrades		CMEV	MVHR	£6,415.87	£54,102.66	£71,168.81	£7,249.94
HVAC	7. Ventilation	Results	EPC rating	B (81)	B (82)				
HVAC	7. Ventilation	Results	Energy demand kWh/m^2/yr	59.1 (65)	49.1 (54)				
HVAC	8. Low Carbon Heat Source	Upgrades		ASHP	ASHP	£12,540.50	£66,643.16	£87,665.08	£14,509.36
HVAC	8. Low Carbon Heat Source	Results	EPC rating	B (81)	B (82)				
HVAC	8. Low Carbon Heat Source	Results	Energy demand kWh/m^2/yr	57.5 (63.2)	48 (52.8)				
Further Fabric	9. Floor Insulation	Upgrades		Floor insulation	Floor insulation	£7,598.00	£74,241.17	£97,659.80	£8,585.74
Further Fabric	9. Floor Insulation	Results	EPC rating	B (85)	B (86)				
Further Fabric	9. Floor Insulation	Results	Energy demand kWh/m^2/yr	41.4 (45.6)	31.2 (34.3)				
Renewable Technology	10. Photovoltaics	Upgrades		PV	PV	£5,433.75	£79,674.92	£104,807.57	£6,259.68
Renewable Technology	10. Photovoltaics	Results	EPC rating	A (92)	A (93)				
Renewable Technology	10. Photovoltaics	Results	kWp	2.2	2.0				
Renewable Technology	10. Photovoltaics	Results	Energy demand kWh/m^2/yr	41.4 (45.6)	31.2 (34.3)				

Contingency @ 5%	£3,983.75	£83,658.66
Subtotal		**£83,658.66**
Prelims @ 16%	£13,385.39	£97,044.05
OH&P @ 8%	£7,763.52	£104,807.57
Total £		**£104,807.57**

Notes

Below DPC EWI may be required (to avoid PAS non-compliance) not included, suggest circa £5,000. Eaves depth/roof may require adjustment to avoid PAS non-compliant detail/junction. Canopy replacement required. Full air pressure testing and careful remedial works will be required to reduce airtightness down to 5.



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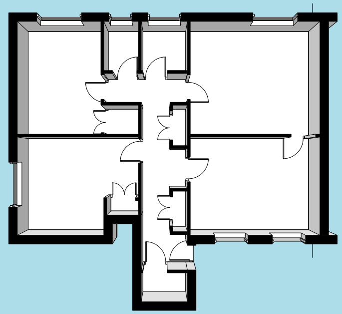
Archetype 5a 1950-1966 ground floor flat, cavity wall - 80.5m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**D (67)**	136.4 (150.1)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	**2. Replace existing cavity fill insulation**			**C (70)**	121.8 (134)	£2,162.81	£2,162.81	£2,845.04	£2,400.71
Fabric First Approach	**3. 150mm EWI**			**C (71)**	113.1 (124.4)	£34,084.90	£36,247.70	£47,681.68	£37,834.23
Fabric First Approach	**4. Double glazing**			**C (72)**	107.6 (118.3)	£4,456.37	£40,704.07	£53,543.76	£4,946.57
Fabric First Approach	**5. Air tightness measures**			**C (75)**	92.1 (101.3)	£1,300.00	£42,004.07	£55,253.83	
Fabric First Approach	**6. Thermal Bridging calculations**			**C (79)**	70.5 (77.5)	£1,000.00	£43,004.07	£56,569.27	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£4,570.56	£47,574.63	£62,581.57	£5,164.73
HVAC		Results	EPC rating	**C (78)**	**C (79)**				
HVAC		Results	Energy demand kWh/m²/yr	72.1 (79.3)	63.1 (69.4)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£10,722.05	£58,296.67	£76,685.78	£12,405.41
HVAC		Results	EPC rating	**C (79)**	**C (79)**				
HVAC		Results	Energy demand kWh/m²/yr	69.6 (76.6)	61.1 (67.2)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£11,312.58	£69,609.26	£91,566.80	£12,783.22
Further Fabric		Results	EPC rating	**B (82)**	**B (83)**				
Further Fabric		Results	Energy demand kWh/m²/yr	48.6 (53.4)	39.3 (43.2)				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£5,433.75	£75,043.01	£98,714.57	£6,259.68
Renewable Technology		Results	EPC rating	**B (91)**	**A (92)**				
Renewable Technology		Results	kWp	2.2	2.0				
Renewable Technology		Results	Energy demand kWh/m²/yr	48.6 (53.4)	39.3 (43.2)				

Contingency @ 5%	£3,752.15	£78,795.16
Subtotal		**£78,795.16**
Prelims @ 16%	£12,607.23	£91,402.38
OH&P @ 8%	£7,312.19	£98,714.57
Total £		**£98,714.57**



Notes

Below DPC EWI may be required to avoid PAS non-compliance not included, suggest circa £3,000. Meter box and cable relocation could present EWI programme and stats cordination difficulties. Location of ASHP condenser unit subject to space and planning constraints.

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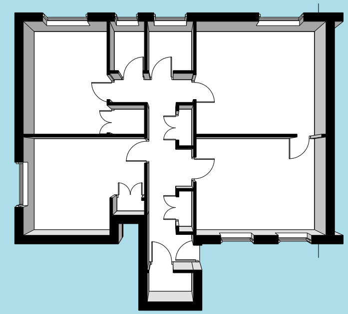
Archetype 5b 1950-1966 first floor flat, cavity wall - 80.5m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**D (68)**	132.2 (145.4)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			**C (70)**	118.8 (130.7)	£2,233.45		£2,937.97	£2,479.13
Fabric First Approach	**2. Replace existing cavity fill insulation**			**C (74)**	98.8 (108.6)	£3,950.14	£6,183.58	£8,134.13	£4,384.65
Fabric First Approach	**3. 150mm EWI**			**C (76)**	86.8 (95.5)	£25,827.90	£32,011.48	£42,109.18	£28,668.96
Fabric First Approach	**4. Double glazing**			**C (77)**	80.3 (88.3)	£4,456.37	£36,467.85	£47,971.27	£4,946.57
Fabric First Approach	**5. Air tightness measures**			**C (80)**	61.8 (68)	£1,300.00	£37,767.85	£49,681.34	
Fabric First Approach	**6. Thermal Bridging calculations**			**B (85)**	35.3 (38.8)	£1,000.00	£38,767.85	£50,996.78	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£4,515.36	£43,283.21	£56,936.46	£5,102.36
		Results	**EPC rating**	**B (84)**	**B (84)**				
			Energy demand kWh/m²/yr	37.3 (41.1)	26.8 (29.5)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£10,475.38	£53,758.59	£70,716.19	£12,120.01
		Results	**EPC rating**	**B (84)**	**B (85)**				
			Energy demand kWh/m²/yr	37.3 (41)	27.1 (29.8)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£0.00	£53,758.59	£70,716.19	£0.00
		Results	**EPC rating**	N/A	N/A				
			Energy demand kWh/m²/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£4,916.25	£58,674.84	£77,183.23	£5,663.52
		Results	**EPC rating**	**A (93)**	**A (94)**				
			kWp	2.0	1.8				
			Energy demand kWh/m²/yr	37.3 (41)	27.1 (29.8)				

Contingency @ 5%	£2,933.74	£61,608.58
Subtotal		**£61,608.58**
Prelims @ 16%	£9,857.37	£71,465.95
OH&P @ 8%	£5,717.28	£77,183.23
Total £		**£77,183.23**

Notes

5b uses 5a floor plan as not fully accessed at time of inspection. Meter box and cable relocation could present EWI programme and stats cordination difficulties. Eaves depth/roof may require adjustment to avoid PAS non-compliant detail/junction. Thinner EWI solution may avoid cost. Detailing around dormer window/window loading potentially problematic - prefabrication potential. Location of ASHP condenser unit subject to space and planning constraints.



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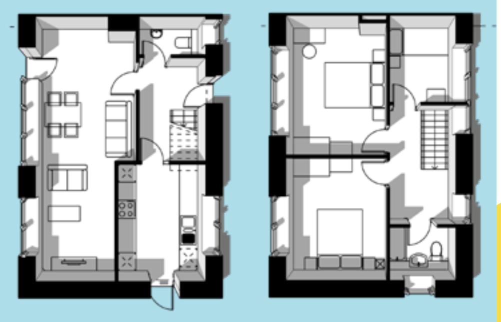
Archetype 6 1950-1966 semi detached system built (Unity) house - 84m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			D (61)	168.8 (185.6)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			D (64)	154.4 (169.8)	£1,619.56		£2,130.43	£1,797.71
Fabric First Approach	**2. Replace existing cavity fill insulation**			C (70)	120.6 (132.7)	£4,951.47	£6,571.03	£8,643.80	£5,496.14
Fabric First Approach	**3. 150mm EWI**			C (70)	116.7 (128.3)	£32,844.00	£39,415.03	£51,848.11	£36,456.84
Fabric First Approach	**4. Double glazing**			C (73)	102.3 (112.5)	£6,126.61	£45,541.64	£59,907.30	£6,800.54
Fabric First Approach	**5. Air tightness measures**			C (75)	89.8 (98.8)	£1,300.00	£46,841.64	£61,617.37	
Fabric First Approach	**6. Thermal Bridging calculations**			C (80)	65.5 (72)	£1,000.00	£47,841.64	£62,932.81	
HVAC	**7. Ventilation**	Upgrades		CMEV	MVHR	£6,014.88	£53,856.52	£70,845.03	£6,796.81
HVAC		Results	EPC rating	C (80)	C (80)				
HVAC		Results	Energy demand kWh/m²/yr	63 (69.3)	53 (58.3)				
HVAC	**8. Low Carbon Heat Source**	Upgrades		ASHP	ASHP	£11,738.64	£65,595.16	£86,286.50	£13,581.60
HVAC		Results	EPC rating	C (80)	C (80)				
HVAC		Results	Energy demand kWh/m²/yr	61.2 (67.4)	53.9 (59.3)				
Further Fabric	**9. Floor Insulation**	Upgrades		Floor insulation	Floor insulation	£11,819.12	£77,414.28	£101,833.84	£13,355.60
Further Fabric		Results	EPC rating	B (82)	B (82)				
Further Fabric		Results	Energy demand kWh/m²/yr	50.4 (55.5)	42.7 (47)				
Renewable Technology	**10. Photovoltaics**	Upgrades		PV	PV	£5,692.50	£83,106.78	£109,321.98	£6,557.76
Renewable Technology		Results	EPC rating	A (92)	A (92)				
Renewable Technology		Results	kWp	2.3	2.1				
Renewable Technology		Results	Energy demand kWh/m²/yr	50.4 (55.5)	42.7 (47)				

Contingency @ 5%	£4,155.34	£87,262.12
Subtotal		**£87,262.12**
Prelims @ 16%	£13,961.94	£101,224.06
OH&P @ 8%	£8,097.92	£109,321.98
Total £		**£109,321.98**



Notes

This is a unity system built home. Below DPC EWI may be required to avoid PAS non-compliance not included, suggest circa £5,000. Cable relocation could present EWI programme and stats cordination difficulties. Side access width reduction may reduce EWI potential/thickness. Structural stability of external wall to accept EWI must be confirmed. Build quility and detailing may not be in accordance with the system details so exploratory surveys are recommended. Canopy and door surround may need removal and careful detailing of windows brought forward in EWI required.

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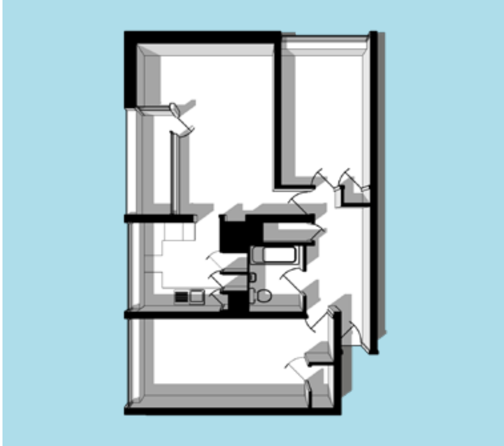
Archetype 7a 1950-1966 ground floor flat system build (Wimpey no-fines) - 78.87m^2

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m^2/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			C (70)	121.2 (133.3)				
Fabric First Approach	1. Top up roof insulation to 400mm			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	2. Replace existing cavity fill insulation			N/A	N/A	£0.00	£0.00	£0.00	£0.00
Fabric First Approach	3. 150mm EWI			C (73)	105.6 (116.2)	£17,566.85	£17,566.85	£23,108.13	£19,499.20
Fabric First Approach	4. Double glazing			C (75)	94.1 (103.6)	£5,382.69	£22,949.54	£30,188.74	£5,974.79
Fabric First Approach	5. Air tightness measures			C (78)	79.6 (87.5)	£1,300.00	£24,249.54	£31,898.81	
Fabric First Approach	6. Thermal Bridging calculations			B (81)	62.5 (68.7)	£1,000.00	£25,249.54	£33,214.25	
HVAC	7. Ventilation	Upgrades		CMEV	MVHR	£4,560.00	£29,809.54	£39,212.66	£5,152.80
HVAC		Results	EPC rating	C (80)	C (80)				
HVAC		Results	Energy demand kWh/m^2/yr	62.5 (68.8)	55.2 (60.8)				
HVAC	8. Low Carbon Heat Source	Upgrades		N/A	N/A	£11,039.65	£40,849.19	£53,734.65	£12,894.31
HVAC		Results	EPC rating	C (70)	C (71)				
HVAC		Results	Energy demand kWh/m^2/yr	60.5 (66.5)	53.2 (58.5)				
Further Fabric	9. Floor Insulation	Upgrades		Floor insulation	Floor insulation	£11,097.31	£51,946.49	£68,332.49	£12,539.96
Further Fabric		Results	EPC rating	C (76)	C (77)				
Further Fabric		Results	Energy demand kWh/m^2/yr	39.5 (43.4)	31.8 (34.9)				
Renewable Technology	10. Photovoltaics	Upgrades		PV	PV	£9,315.00	£61,261.49	£80,585.82	£10,730.88
Renewable Technology		Results	EPC rating	B (85)	B (85)				
Renewable Technology		Results	kWp	3.7	3.5				
Renewable Technology		Results	Energy demand kWh/m^2/yr	39.5 (43.4)	31.8 (34.9)				

Contingency @ 5%	£3,063.07	£64,324.57
Subtotal		£64,324.57
Prelims @ 16%	£10,291.93	£74,616.50
OH&P @ 8%	£5,969.32	£80,585.82
Total £		£80,585.82

Notes

This unit sits on a podium therefore the floor insulation could be brought forward in sequence. The EWI detailing around the internal balcony will be problematic. EWI loadings/fixings into No fines will need consideration The units are modelled using GSHP with water to water heat pumps and heat store but this requires available external area for boreholes or ground loops. There is potential to use high efficiency electric heating with air to water heat pumps for hot water. This modelling is theoretical and each block will be different. The works to this block would likely be carried out as part of a strategic asset management plan.



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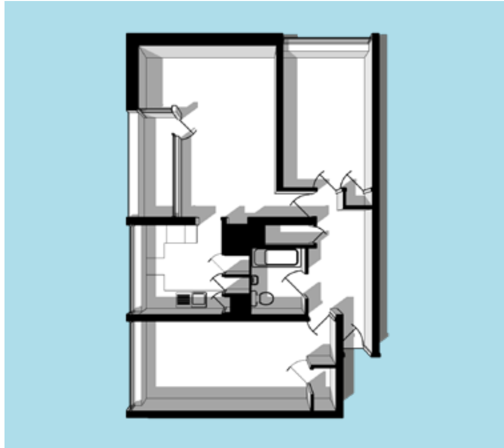
Archetype 7b 1950-1966 mid floor flat system build (Wimpey no-fines) - 78.87m²

	Upgrades			Results		Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
				EPC rating (SAP score)	Space heating demand kWh/m²/yr SAP (PHPP) values				
	Existing			C (74)	99 (108.9)				
Fabric First Approach	1. Top up roof insulation to 400mm			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	2. Replace existing cavity fill insulation			N/A	N/A	£0.00	£0.00	£0.00	£0.00
Fabric First Approach	3. 150mm EWI			B (81)	62.8 (69.1)	£17,879.65	£17,879.65	£23,519.60	£19,846.41
Fabric First Approach	4. Double glazing			B (83)	48.6 (53.5)	£5,382.69	£23,262.34	£30,600.21	£5,974.79
Fabric First Approach	5. Air tightness measures			B (86)	31.3 (34.4)	£1,300.00	£24,562.34	£32,310.28	
Fabric First Approach	6. Thermal Bridging calculations			B (87)	23.3 (25.6)	£1,000.00	£25,562.34	£33,625.72	
HVAC	7. Ventilation	Upgrades		CMEV	MVHR	£4,560.00	£30,122.34	£39,624.13	£5,152.80
		Results	EPC rating	B (86)	B (86)				
			Energy demand kWh/m²/yr	23.4 (25.7)	13.7 (15)				
HVAC	8. Low Carbon Heat Source	Upgrades		ASHP	ASHP	£11,039.65	£41,161.99	£54,146.12	£12,772.87
		Results	EPC rating	B (81)	B (81)				
			Energy demand kWh/m²/yr	21.6 (23.8)	14.2 (15.6)				
Further Fabric	9. Floor Insulation	Upgrades		Floor insulation	Floor insulation	£0.00	£41,161.99	£54,146.12	£0.00
		Results	EPC rating	N/A	N/A				
			Energy demand kWh/m²/yr	N/A	N/A				
Renewable Technology	10. Photovoltaics	Upgrades		PV	PV	£6,727.50	£47,889.49	£62,995.75	£7,750.08
		Results	EPC rating	B (85)	B (85)				
			kWp	2.7	2.5				
			Energy demand kWh/m²/yr	21.6 (23.8)	14.2 (15.6)				

Contingency @ 5%	£2,394.47	£50,283.96
Subtotal		£50,283.96
Prelims @ 16%	£8,045.43	£58,329.39
OH&P @ 8%	£4,666.35	£62,995.75
Total £		£62,995.75



Notes

This mid floor unit performs significantly better than ground and top floor units due to the significantly better form factor. The EWI detailing around the internal balcony will be problematic. EWI loadings/fixings into No fines will need consideration. The units are modelled using GSHP with water to water heat pumps and heat store but this requires available external area for boreholes or ground loops. There is potential to use high efficiency electric heating with air to water heat pumps for hot water. This modelling is theoretical and each block will be different. The works to this block would likely be carried out as part of a strategic asset management plan.

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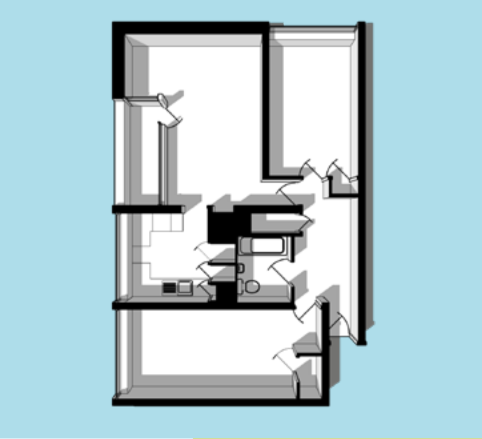
Archetype 7c 1950-1966 top floor flat system build (Wimpey no-fines) - 78.87m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**C (70)**	123.2 (135.6)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			**C (72)**	111.2 (122.3)	£2,433.04		£3,200.52	£2,700.68
Fabric First Approach	**2. Replace existing cavity fill insulation**			N/A	N/A	£0.00	£2,433.04	£3,200.52	£0.00
Fabric First Approach	**3. 150mm EWI**			**C (78)**	76.8 (84.4)	£17,879.65	£20,312.69	£26,720.12	£19,846.41
Fabric First Approach	**4. Double glazing**			**C (80)**	63.5 (69.9)	£5,382.69	£25,695.38	£33,800.73	£5,974.79
Fabric First Approach	**5. Air tightness measures**			**B (83)**	47 (51.7)	£1,300.00	£26,995.38	£35,510.80	
Fabric First Approach	**6. Thermal Bridging calculations**			**B (86)**	27.8 (30.6)	£1,000.00	£27,995.38	£36,826.24	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£4,560.00	£32,555.38	£42,824.65	£5,152.80
HVAC		Results	EPC rating	**B (86)**	**B (86)**				
HVAC		Results	Energy demand kWh/m²/yr	27.9 (30.7)	17.9 (19.7)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£11,039.65	£43,595.03	£57,346.64	£12,772.87
HVAC		Results	EPC rating	**C (80)**	**C (80)**				
HVAC		Results	Energy demand kWh/m²/yr	26 (28.6)	18.4 (20.3)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£0.00	£43,595.03	£57,346.64	£0.00
Further Fabric		Results	EPC rating	N/A	N/A				
Further Fabric		Results	Energy demand kWh/m²/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£6,986.25	£50,581.28	£66,536.64	£8,048.16
Renewable Technology		Results	EPC rating	**B (85)**	**B (85)**				
Renewable Technology		Results	kWp	2.8	2.6				
Renewable Technology		Results	Energy demand kWh/m²/yr	26 (28.6)	18.4 (20.3)				

Contingency @ 5%	£2,529.06	£53,110.34
Subtotal		**£53,110.34**
Prelims @ 16%	£8,497.65	£61,608.00
OH&P @ 8%	£4,928.64	£66,536.64
Total £		**£66,536.64**

Notes
Roof top-up insulation has been priced as insulation only and would only be done as part of roof covering replacement under planned works as part of MTIP. Comms equipment req early engagement. The EWI detailing around the internal balcony will be problematic. EWI loadings/fixings into No fines will need consideration. The units are modelled using GSHP with water to water heat pumps and heat store but this requires available external area for boreholes or ground loops. There is potential to use high efficiency electric heating with air to water heat pumps for hot water. This modelling is theoretical and each block will be different. The works to this block would likely be carried out as part of a strategic asset management plan.



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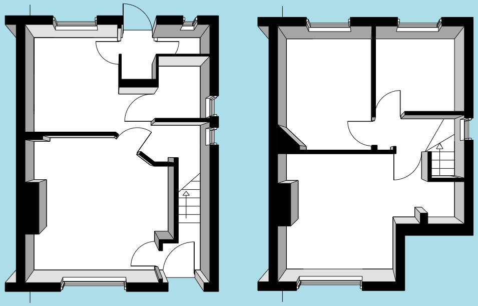
Archetype 8a 1950-1966 end of terrace house, solid wall - 65.6m^2

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m^2/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**D (58)**	195.4 (215)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			**D (59)**	190.5 (209.5)	£1,293.33		£1,701.30	£1,435.60
Fabric First Approach	**2. Replace existing cavity fill insulation**			N/A	N/A	£0.00	£1,293.33	£1,701.30	£0.00
Fabric First Approach	**3. 150mm EWI**			**C (73)**	103.2 (113.5)	£26,143.82	£27,437.16	£36,091.93	£29,019.64
Fabric First Approach	**4. Double glazing**			**C (75)**	93.8 (103.2)	£5,343.35	£32,780.51	£43,120.79	£5,931.12
Fabric First Approach	**5. Air tightness measures**			**C (78)**	74.7 (82.2)	£1,300.00	£34,080.51	£44,830.86	
Fabric First Approach	**6. Thermal Bridging calculations**			**B (81)**	54 (59.4)	£1,000.00	£35,080.51	£46,146.30	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£5,732.18	£40,812.69	£53,686.64	£6,477.36
HVAC		Results	EPC rating	**B (81)**	**B (82)**				
HVAC		Results	Energy demand kWh/m^2/yr	51.5 (56.6)	41.1 (45.2)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£11,173.33	£51,986.01	£68,384.48	£12,927.54
HVAC		Results	EPC rating	**B (81)**	**B (82)**				
HVAC		Results	Energy demand kWh/m^2/yr	50.4 (55.4)	40.5 (44.6)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£9,438.41	£61,424.42	£80,800.14	£10,665.40
Further Fabric		Results	EPC rating	**B (83)**	**B (85)**				
Further Fabric		Results	Energy demand kWh/m^2/yr	38.7 (42.6)	28.4 (31.2)				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£4,916.25	£66,340.67	£87,267.17	£5,663.52
Renewable Technology		Results	EPC rating	**A (93)**	**A (94)**				
Renewable Technology		Results	kWp	2.0	1.8				
Renewable Technology		Results	Energy demand kWh/m^2/yr	38.7 (42.6)	28.4 (31.2)				

Contingency @ 5%	£3,317.03	£69,657.70
Subtotal		**£69,657.70**
Prelims @ 16%	£11,145.23	£80,802.94
OH&P @ 8%	£6,464.23	£87,267.17
Total £		**£87,267.17**

Notes

Below DPC EWI may be required (to avoid PAS non-compliance) not included, suggest circa £5,000. EWI will require careful detailing to wall and sloping roof junction and could be problematic. Full air pressure testing and careful remedial works will be required to reduce airtightness down to 5.



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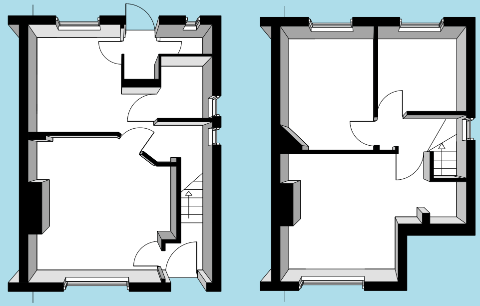
Archetype 8b 1950-1966 mid-terrace house, solid wall - 67.0m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			D (65)	147 (161.7)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			D (66)	141.1 (155.2)	£1,467.63		£1,930.58	£1,629.07
Fabric First Approach	**2. Replace existing cavity fill insulation**			N/A	N/A	£0.00	£1,467.63	£1,930.58	£0.00
Fabric First Approach	**3. 150mm EWI**			C (77)	78.5 (86.4)	£15,380.38	£16,848.01	£22,162.54	£17,072.22
Fabric First Approach	**4. Double glazing**			C (79)	69.5 (76.4)	£4,903.43	£21,751.44	£28,612.71	£5,442.81
Fabric First Approach	**5. Air tightness measures**			B (82)	49.5 (54.4)	£1,300.00	£23,051.44	£30,322.79	
Fabric First Approach	**6. Thermal Bridging calculations**			B (86)	26.5 (29.1)	£1,000.00	£24,051.44	£31,638.23	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£5,883.22	£29,934.66	£39,377.25	£6,648.04
		Results	EPC rating	B (86)	B (86)				
		Results	Energy demand kWh/m²/yr	24.2 (26.6)	13.8 (15.2)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£11,475.36	£41,410.02	£54,472.40	£13,276.99
		Results	EPC rating	B (87)	B (89)				
		Results	Energy demand kWh/m²/yr	24.3 (26.7)	14.2 (15.6)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£10,710.37	£52,120.39	£68,561.25	£12,102.72
		Results	EPC rating	B (87)	B (89)				
		Results	Energy demand kWh/m²/yr	24.3 (26.7)	14.2 (15.6)				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£2,846.25	£54,966.64	£72,305.32	£3,278.88
		Results	EPC rating	A (92)	A (94)				
		Results	kWp	1.2	1.0				
		Results	Energy demand kWh/m²/yr	24.3 (26.7)	14.2 (15.6)				

Contingency @ 5%	£2,748.33	£57,714.97
Subtotal		**£57,714.97**
Prelims @ 16%	£9,234.40	£66,949.37
OH&P @ 8%	£5,355.95	£72,305.32
Total £		**£72,305.32**

Notes

Access to sloping roof void section for insulation and cold roof ventilation may be problematic. EWI will require careful detailing to wall and sloping roof junction and could be problematic. Full air pressure testing and careful remedial works will be required to reduce airtightness down to 5.



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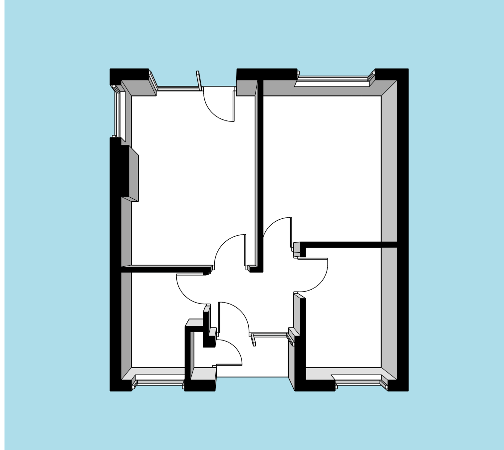
Archetype 9 1950-1966 detached bungalow, cavity wall - 40.6m^2

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m^2/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			D (67)	167.5 (184.2)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			C (69)	156.2 (171.8)	£1,403.43		£1,846.13	£1,557.81
Fabric First Approach	**2. Replace existing cavity fill insulation**			C (72)	133.7 (147)	£3,069.95	£4,473.38	£5,884.46	£3,407.64
Fabric First Approach	**3. 150mm EWI**			C (73)	120.1 (132.1)	£21,655.14	£26,128.53	£34,370.51	£24,037.21
Fabric First Approach	**4. Double glazing**			C (75)	106.4 (117)	£5,271.82	£31,400.34	£41,305.27	£5,851.72
Fabric First Approach	**5. Air tightness measures**			C (77)	95 (104.4)	£1,300.00	£32,700.34	£43,015.34	
Fabric First Approach	**6. Thermal Bridging calculations**			C (79)	76.9 (84.6)	£1,000.00	£33,700.34	£44,330.78	
HVAC	**7. Ventilation**	Upgrades		CMEV	MVHR	£5,272.38	£38,972.72	£51,266.27	£5,957.79
		Results	EPC rating	C (79)	C (80)				
			Energy demand kWh/m^2/yr	73.1 (80.4)	63.5 (69.9)				
HVAC	**8. Low Carbon Heat Source**	Upgrades		ASHP	ASHP	£10,253.86	£49,226.58	£64,754.61	£11,863.71
		Results	EPC rating	C (77)	C (77)				
			Energy demand kWh/m^2/yr	70.7 (77.8)	61.7 (67.9)				
Further Fabric	**9. Floor Insulation**	Upgrades		Floor insulation	Floor insulation	£5,566.24	£54,792.82	£72,076.66	£6,289.85
		Results	EPC rating	C (80)	B (81)				
			Energy demand kWh/m^2/yr	49.6 (54.6)	39.8 (43.8)				
Renewable Technology	**10. Photovoltaics**	Upgrades		PV	PV	£4,916.25	£59,709.07	£78,543.69	£5,663.52
		Results	EPC rating	A (92)	A (94)				
			kWp	2.0	1.8				
			Energy demand kWh/m^2/yr	49.6 (54.6)	39.8 (43.8)				



Contingency @ 5%	£2,985.45	£62,694.52
Subtotal		**£62,694.52**
Prelims @ 16%	£10,031.12	£72,725.64
OH&P @ 8%	£5,818.05	£78,543.69
Total £		**£78,543.69**

Notes

Bungalow form factor (external heat loss area to usable floor area ratio) makes achieving energy demand targets very difficult. Low roof pitch may make installation of insulation and air tightness measures difficult. Below DPC EWI may be required to avoid PAS non-compliance not included, suggest circa £4,000. Meter box and cable relocation could present EWI programme and stats cordination difficulties.

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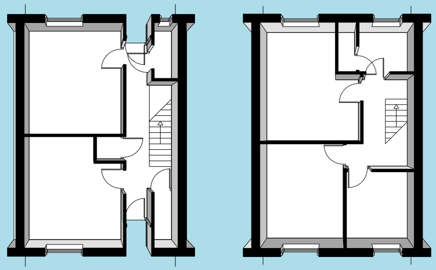
Archetype 10 1966-75 mid-terrace house, cavity wall - 88.3m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**D (68)**	127.1 (139.8)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			**C (70)**	120.7 (132.8)	£1,694.17		£2,228.59	£1,880.53
Fabric First Approach	**2. Replace existing cavity fill insulation**			**C (73)**	102.6 (112.9)	£2,744.81	£4,438.98	£5,839.22	£3,046.74
Fabric First Approach	**3. 150mm EWI**			**C (75)**	91.8 (101)	£19,337.30	£23,776.28	£31,276.27	£21,464.40
Fabric First Approach	**4. Double glazing**			**C (76)**	86.5 (95.2)	£4,688.84	£28,465.12	£37,444.16	£5,204.61
Fabric First Approach	**5. Air tightness measures**			**C (78)**	73.8 (81.1)	£1,300.00	£29,765.12	£39,154.23	
Fabric First Approach	**6. Thermal Bridging calculations**			**B (83)**	49.3 (54.3)	£1,000.00	£30,765.12	£40,469.67	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£6,079.54	£36,844.66	£48,466.94	£6,869.88
HVAC		Results	EPC rating	**B (83)**	**B (83)**				
HVAC		Results	Energy demand kWh/m²/yr	46.8 (51.5)	39.8 (43.8)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**ASHP**	**ASHP**	£11,867.94	£48,712.60	£64,078.50	£13,731.21
HVAC		Results	EPC rating	**B (83)**	**B (84)**				
HVAC		Results	Energy demand kWh/m²/yr	45.6 (50.2)	39 (42.9)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£12,363.64	£61,076.24	£80,342.13	£13,970.91
Further Fabric		Results	EPC rating	**B (85)**	**B (86)**				
Further Fabric		Results	Energy demand kWh/m²/yr	34.3 (37.8)	27.4 (30.1)				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£4,398.75	£65,474.99	£86,128.42	£5,067.36
Renewable Technology		Results	EPC rating	**A (92)**	**A (93)**				
Renewable Technology		Results	kWp	1.8	1.6				
Renewable Technology		Results	Energy demand kWh/m²/yr	34.3 (37.8)	27.4 (30.1)				

Contingency @ 5%	£3,273.75	£68,748.74
Subtotal		**£68,748.74**
Prelims @ 16%	£10,999.80	£79,748.54
OH&P @ 8%	£6,379.88	£86,128.42
Total £		**£86,128.42**

Notes

Relatively low roof pitch may make installation of insulation and air tightness measures difficult. Below DPC EWI may be required to avoid PAS non-compliance not included, suggest circa £2,000. Eaves depth/roof may require adjustment to avoid PAS non-compliant detail/junction. Thinner EWI may be possible to avoid re detailing issues/costs. Canopy replacement required.



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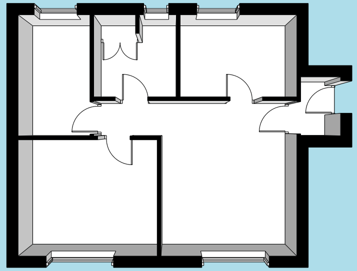
Archetype 11a 1966-1975 ground floor flat, cavity wall - 48.4m^2

	Upgrades			Results		Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
				EPC rating (SAP score)	Space heating demand kWh/m^2/yr SAP (PHPP) values				
	Existing			D (66)	161.9 (178.1)				
Fabric First Approach	1. Top up roof insulation to 400mm			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	2. Replace existing cavity fill insulation			C (69)	140.7 (154.8)	£3,619.92	£3,619.92	£4,761.79	£4,018.12
Fabric First Approach	3. 150mm EWI			C (70)	132.7 (145.9)	£23,072.13	£26,692.05	£35,111.79	£25,610.06
Fabric First Approach	4. Double glazing			C (71)	126 (138.6)	£3,404.86	£30,096.92	£39,590.69	£3,779.40
Fabric First Approach	5. Air tightness measures			C (73)	108.6 (119.4)	£1,300.00	£31,396.92	£41,300.76	
Fabric First Approach	6. Thermal Bridging calculations			C (77)	83.2 (91.5)	£1,000.00	£32,396.92	£42,616.20	
HVAC	7. Ventilation	Upgrades		CMEV	MVHR	£4,349.42	£36,746.33	£48,337.59	£4,914.84
		Results	EPC rating	C (76)	C (77)				
			Energy demand kWh/m^2/yr	84.9 (93.4)	76.2 (83.8)				
HVAC	8. Low Carbon Heat Source	Upgrades		ASHP	ASHP	£9,733.84	£46,480.17	£61,141.87	£11,262.05
		Results	EPC rating	C (75)	C (76)				
			Energy demand kWh/m^2/yr	82.6 (90.9)	74.4 (81.8)				
Further Fabric	9. Floor Insulation	Upgrades		Floor insulation	Floor insulation	£6,803.03	£53,283.19	£70,090.84	£7,687.42
		Results	EPC rating	C (78)	C (79)				
			Energy demand kWh/m^2/yr	62.3 (68.5)	53.3 (58.6)				
Renewable Technology	10. Photovoltaics	Upgrades		PV	PV	£6,468.75	£59,751.94	£78,600.10	£7,452.00
		Results	EPC rating	A (93)	A (94)				
			kWp	2.6	2.4				
			Energy demand kWh/m^2/yr	62.3 (68.5)	53.3 (58.6)				

Contingency @ 5%	£2,987.60	£62,739.54
Subtotal		**£62,739.54**
Prelims @ 16%	£10,038.33	£72,777.87
OH&P @ 8%	£5,822.23	£78,600.10
Total £		**£78,600.10**

Notes

Below DPC EWI may be required to avoid PAS non-compliance not included, suggest circa £4,000. Cable relocation could present EWI programme and stats cordination difficulties. Side access width reduction may reduce EWI potential/thickness. Location of ASHP condenser unit subject to space and planning constraints.



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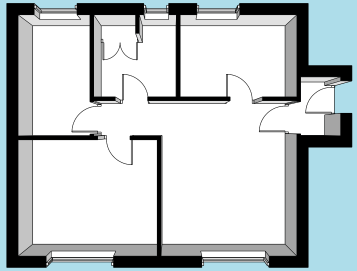
Archetype 11b 1966-1975 mid-floor flat, cavity wall - 48.4m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			C (71)	123.5 (135.8)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	**2. Replace existing cavity fill insulation**			C (75)	98.9 (108.7)	£3,619.92	£3,619.92	£4,761.79	£4,018.12
Fabric First Approach	**3. 150mm EWI**			C (77)	83.9 (92.3)	£23,072.13	£26,692.05	£35,111.79	£25,610.06
Fabric First Approach	**4. Double glazing**			C (78)	75.1 (82.7)	£3,404.86	£30,096.92	£39,590.69	£3,779.40
Fabric First Approach	**5. Air tightness measures**			B (81)	54.1 (59.5)	£1,300.00	£31,396.92	£41,300.76	
Fabric First Approach	**6. Thermal Bridging calculations**			B (83)	36 (39.6)	£1,000.00	£32,396.92	£42,616.20	
HVAC	**7. Ventilation**	Upgrades		CMEV	MVHR	£4,349.42	£36,746.33	£48,337.59	£4,914.84
HVAC		Results	EPC rating	B (83)	B (83)				
HVAC		Results	Energy demand kWh/m²/yr	38 (41.8)	27.9 (30.7)				
HVAC	**8. Low Carbon Heat Source**	Upgrades		ASHP	ASHP	£9,733.84	£46,480.17	£61,141.87	£11,262.05
HVAC		Results	EPC rating	B (83)	B (84)				
HVAC		Results	Energy demand kWh/m²/yr	38 (41.8)	28.3 (31.1)				
Further Fabric	**9. Floor Insulation**	Upgrades		Floor insulation	Floor insulation	£0.00	£46,480.17	£61,141.87	£0.00
Further Fabric		Results	EPC rating	N/A	N/A				
Further Fabric		Results	Energy demand kWh/m²/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	Upgrades		PV	PV	£4,916.25	£51,396.42	£67,608.90	£5,663.52
Renewable Technology		Results	EPC rating	A (94)	A (95)				
Renewable Technology		Results	kWp	2.0	1.8				
Renewable Technology		Results	Energy demand kWh/m²/yr	38 (41.8)	28.3 (31.1)				

Contingency @ 5%	£2,569.82	£53,966.24
Subtotal		**£53,966.24**
Prelims @ 16%	£8,634.60	£62,600.84
OH&P @ 8%	£5,008.07	£67,608.90
Total £		**£67,608.90**

Notes

Cable relocation could present EWI programme and stats cordination difficulties. Side access width reduction may reduce EWI potential/thickness. Location of ASHP condenser unit subject to space and planning constraints.



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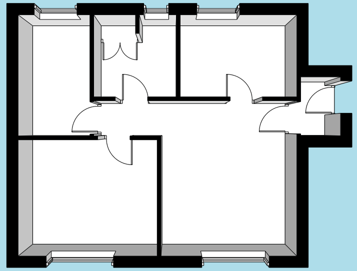
Archetype 11c 1966-1975 top floor flat, cavity wall - 48.4m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			D (68)	148.2 (163)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			C (69)	135.9 (149.5)	£1,864.81		£2,453.04	£2,069.94
Fabric First Approach	**2. Replace existing cavity fill insulation**			C (73)	112.4 (123.7)	£3,619.92	£5,484.73	£7,214.83	£4,018.12
Fabric First Approach	**3. 150mm EWI**			C (75)	98.2 (108.1)	£23,072.13	£28,556.86	£37,564.83	£25,610.06
Fabric First Approach	**4. Double glazing**			C (76)	90.1 (99.1)	£3,404.86	£31,961.72	£42,043.73	£3,779.40
Fabric First Approach	**5. Air tightness measures**			C (79)	70.2 (77.2)	£1,300.00	£33,261.72	£43,753.80	
Fabric First Approach	**6. Thermal Bridging calculations**			B (83)	40.9 (45)	£1,000.00	£34,261.72	£45,069.24	
HVAC	**7. Ventilation**	Upgrades		CMEV	MVHR	£4,349.42	£38,611.14	£50,790.64	£4,914.84
HVAC		Results	EPC rating	B (82)	B (83)				
HVAC		Results	Energy demand kWh/m²/yr	42.9 (47.2)	32.9 (36.2)				
HVAC	**8. Low Carbon Heat Source**	Upgrades		ASHP	ASHP	£9,733.84	£48,344.97	£63,594.91	£11,262.05
HVAC		Results	EPC rating	B (82)	B (83)				
HVAC		Results	Energy demand kWh/m²/yr	42.7 (47)	33.1 (36.4)				
Further Fabric	**9. Floor Insulation**	Upgrades		Floor insulation	Floor insulation	£0.00	£48,344.97	£63,594.91	£0.00
Further Fabric		Results	EPC rating	N/A	N/A				
Further Fabric		Results	Energy demand kWh/m²/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	Upgrades		PV	PV	£4,916.25	£53,261.22	£70,061.94	£5,663.52
Renewable Technology		Results	EPC rating	A (93)	A (94)				
Renewable Technology		Results	kWp	2.0	1.8				
Renewable Technology		Results	Energy demand kWh/m²/yr	42.7 (47)	33.1 (36.4)				

Contingency @ 5%	£2,663.06	£55,924.28
Subtotal		**£55,924.28**
Prelims @ 16%	£8,947.89	£64,872.17
OH&P @ 8%	£5,189.77	£70,061.94
Total £		**£70,061.94**

Notes

Roof top-up insulation has been priced as insulation only and would only be done as part of roof replacement under planned works as part of MTIP. Cable relocation could present EWI programme and stats cordination difficulties. Side access width reduction may reduce EWI potential/thickness. Location of ASHP condenser unit subject to space and planning constraints.



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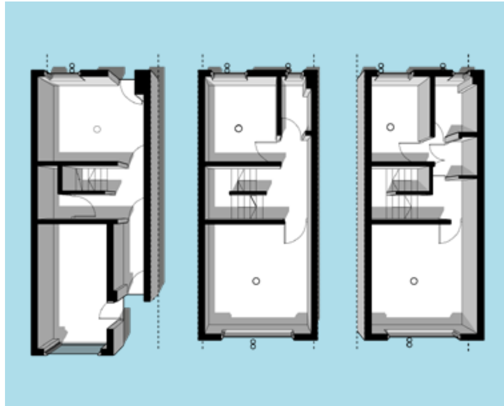
Archetype 12 1966-1975 mid terrace town house, cavity wall - 96m²

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			C (72)	105.3 (115.8)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			C (75)	91.5 (100.6)	£1,125.98		£1,481.16	£1,249.84
Fabric First Approach	**2. Replace existing cavity fill insulation**			C (78)	76 (83.6)	£2,315.99	£3,441.96	£4,527.70	£2,570.74
Fabric First Approach	**3. 150mm EWI**			C (79)	71.5 (78.6)	£15,170.80	£18,612.76	£24,483.97	£16,839.59
Fabric First Approach	**4. Double glazing**			C (80)	66.6 (73.3)	£2,646.64	£21,259.40	£27,965.47	£2,937.77
Fabric First Approach	**5. Air tightness measures**			B (83)	49.1 (54)	£1,300.00	£22,559.40	£29,675.54	
Fabric First Approach	**6. Thermal Bridging calculations**			B (85)	35.3 (38.8)	£1,000.00	£23,559.40	£30,990.98	
HVAC	**7. Ventilation**	Upgrades		CMEV	MVHR	£6,215.38	£29,774.78	£39,166.93	£7,023.37
		Results	EPC rating	B (85)	B (85)				
			Energy demand kWh/m²/yr	36.9 (40.6)	28.7 (31.6)				
HVAC	**8. Low Carbon Heat Source**	Upgrades		ASHP	ASHP	£12,139.57	£41,914.35	£55,135.81	£14,045.48
		Results	EPC rating	B (85)	B (86)				
			Energy demand kWh/m²/yr	36.2 (39.8)	28.4 (31.2)				
Further Fabric	**9. Floor Insulation**	Upgrades		Floor insulation	Floor insulation	£13,507.56	£55,421.91	£72,904.20	£15,263.54
		Results	EPC rating	B (86)	B (87)				
			Energy demand kWh/m²/yr	30.5 (33.6)	22.6 (24.8)				
Renewable Technology	**10. Photovoltaics**	Upgrades		PV	PV	£3,881.25	£59,303.16	£78,009.75	£4,471.20
		Results	EPC rating	A (93)	A (93)				
			kWp	1.6	1.4				
			Energy demand kWh/m²/yr	30.5 (33.6)	22.6 (24.8)				

Contingency @ 5%	£2,965.16	£62,268.32
Subtotal		**£62,268.32**
Prelims @ 16%	£9,962.93	£72,231.25
OH&P @ 8%	£5,778.50	£78,009.75
Total £		**£78,009.75**

Notes

Relatively low roof pitch may make installation of insulation, loft hatch adaptation and air tightness measures difficult. Below DPC EWI may be required to avoid PAS non-compliance not included, suggest circa £2,000. Tile hung façade will provide very difficult EWI detailing issues at party wall junction and may only be possible to undertake with adjoining property. Recessed porch and porch roof also problematic. Semi heated garage abutment also to be considered. Exploratory surveys will be necessary to finalise bespoke design details.



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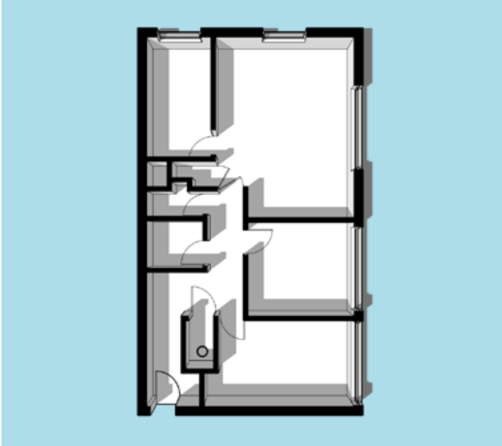
Archetype 13a 1966-1975 ground floor flat, cavity wall and pre cast concrete panels - 79.97m²

	Upgrades			Results		Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
				EPC rating	Space heating demand kWh/m²/yr				
				(SAP score)	SAP (PHPP) values				
	Existing			D (66)	144.4 (158.9)				
Fabric First Approach	1. Top up roof insulation to 400mm			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	2. Replace existing cavity fill insulation			D (67)	137.6 (151.4)	£5,023.60	£5,023.60	£6,608.25	£5,576.20
Fabric First Approach	3. 150mm EWI			C (70)	123.5 (135.9)	£30,107.00	£35,130.60	£46,212.20	£33,418.77
Fabric First Approach	4. Double glazing			C (72)	112.6 (123.8)	£2,539.34	£37,669.94	£49,552.55	£2,818.67
Fabric First Approach	5. Air tightness measures			C (74)	98.8 (108.7)	£1,300.00	£38,969.94	£51,262.62	
Fabric First Approach	6. Thermal Bridging calculations			C (78)	76.9 (84.6)	£1,000.00	£39,969.94	£52,578.06	
HVAC	7. Ventilation	Upgrades		CMEV	MVHR	£4,560.00	£44,529.95	£58,576.47	£5,152.80
HVAC	7. Ventilation	Results	EPC rating	C (77)	C (78)				
HVAC	7. Ventilation	Results	Energy demand kWh/m²/yr	76.9 (84.6)	67.8 (74.6)				
HVAC	8. Low Carbon Heat Source	Upgrades		GSHP	GSHP	£11,039.65	£55,569.59	£73,098.47	£12,894.31
HVAC	8. Low Carbon Heat Source	Results	EPC rating	D (65)	D (67)				
HVAC	8. Low Carbon Heat Source	Results	Energy demand kWh/m²/yr	74.6 (82.1)	67.5 (74.3)				
Further Fabric	9. Floor Insulation	Upgrades		Floor insulation	Floor insulation	£11,097.31	£66,666.90	£87,696.31	£12,539.96
Further Fabric	9. Floor Insulation	Results	EPC rating	C (72)	C (74)				
Further Fabric	9. Floor Insulation	Results	Energy demand kWh/m²/yr	53.2 (58.5)	45.4 (50)				
Renewable Technology	10. Photovoltaics	Upgrades		PV	PV	£11,643.75	£78,310.65	£103,012.96	£17,698.50
Renewable Technology	10. Photovoltaics	Results	EPC rating	B (84)	B (85)				
Renewable Technology	10. Photovoltaics	Results	kWp	4.2	4.0				
Renewable Technology	10. Photovoltaics	Results	Energy demand kWh/m²/yr	53.2 (58.5)	45.42 (50)				

Contingency @ 5%	£3,915.53	£82,226.18
Subtotal		£82,226.18
Prelims @ 16%	£13,156.19	£95,382.37
OH&P @ 8%	£7,630.59	£103,012.96
Total £		£103,012.96

Notes

This unit sits on a exposed podium therefore the floor insulation could be brought forward in sequence. The relacement of cavity wall insulation is only partial to end flanks of units. The units are modelled using GSHP with water to water heat pumps and heat store but this requires available external area for boreholes or ground loops. There is potential to use high efficiency electric heating with air to water heat pumps for hot water. This modelling is theoretical and each block will be different. The works to this block would likely be carried out as part of a strategic asset management plan.



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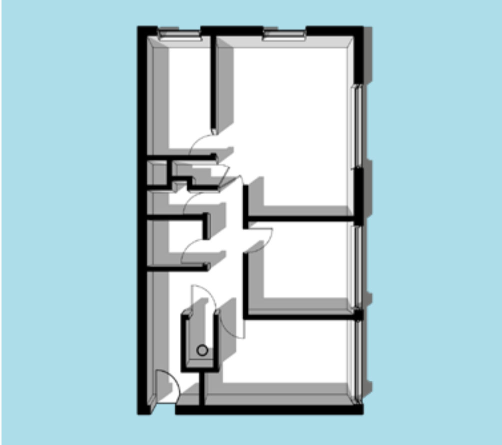
Archetype 13b 1966-1975 ground floor flat, cavity wall and pre cast concrete panels - 79.97m2

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			C (70)	122.8 (135.1)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			N/A	N/A	£0.00		£0.00	£0.00
Fabric First Approach	**2. Replace existing cavity fill insulation**			C (74)	97.5 (107.3)	£5,023.60	£5,023.60	£6,608.25	£5,576.20
Fabric First Approach	**3. 150mm EWI**			C (77)	81 (89.1)	£30,419.80	£35,443.40	£46,623.67	£33,765.98
Fabric First Approach	**4. Double glazing**			C (79)	67.8 (74.6)	£2,897.00	£38,340.40	£50,434.49	£3,215.67
Fabric First Approach	**5. Air tightness measures**			B (82)	51 (56.1)	£1,300.00	£39,640.40	£52,144.57	
Fabric First Approach	**6. Thermal Bridging calculations**			B (85)	36.4 (40)	£1,000.00	£40,640.40	£53,460.01	
HVAC	**7. Ventilation**	Upgrades		CMEV	MVHR	£4,560.00	£45,200.40	£59,458.42	£5,152.80
		Results	EPC rating	B (84)	B (85)				
			Energy demand kWh/m²/yr	36.4 (40.1)	25.5 (28)				
HVAC	**8. Low Carbon Heat Source**	Upgrades		GSHP	GSHP	£11,039.65	£56,240.05	£73,980.41	£12,894.31
		Results	EPC rating	C (78)	C (79)				
			Energy demand kWh/m²/yr	34 (37.4)	25.5 (28.1)				
Further Fabric	**9. Floor Insulation**	Upgrades		Floor insulation	Floor insulation	£0.00	£56,240.05	£73,980.41	£0.00
		Results	EPC rating	N/A	N/A				
			Energy demand kWh/m²/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	Upgrades		PV	PV	£8,021.25	£64,261.30	£84,531.88	£9,240.48
		Results	EPC rating	B (87)	B (87)				
			kWp	3.2	3.0				
			Energy demand kWh/m²/yr	34 (37.4)	25.5 (28.1)				

Contingency @ 5%	£3,213.06	£67,474.36
Subtotal		**£67,474.36**
Prelims @ 16%	£10,795.90	£78,270.26
OH&P @ 8%	£6,261.62	£84,531.88
Total £		**£84,531.88**

Notes

This mid floor unit performs significantly better that ground and top floor units due to the better form factor. The relacement of cavity wall insulation is only partial to end flanks of units. The units are modelled using GSHP with water to water heat pumps and heat store but this requires available external area for boreholes or ground loops. There is potential to use high efficiency electric heating with air to water heat pumps for hot water (fig 45). This modelling is theoretical and each block will be different. The works to this block would likely be carried out as part of a strategic asset management plan.



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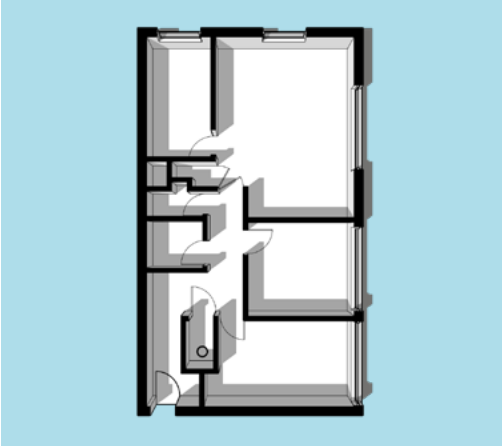
Archetype 13c 1966-1975 ground floor flat, cavity wall and pre cast concrete panels - 79.97m^2

	Upgrades			Results: EPC rating (SAP score)	Results: Space heating demand kWh/m^2/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing			**D (65)**	146.4 (161.1)				
Fabric First Approach	**1. Top up roof insulation to 400mm**			**D (68)**	134.7 (148.1)	£2,798.00		£3,680.60	£3,105.78
Fabric First Approach	**2. Replace existing cavity fill insulation**			**C (72)**	110.5 (121.6)	£5,023.60	£7,821.60	£10,288.84	£5,576.20
Fabric First Approach	**3. 150mm EWI**			**C (75)**	94.9 (104.4)	£30,732.60	£38,554.20	£50,715.74	£34,113.19
Fabric First Approach	**4. Double glazing**			**C (77)**	82.5 (90.8)	£3,254.65	£41,808.85	£54,997.03	£3,612.66
Fabric First Approach	**5. Air tightness measures**			**C (80)**	66.9 (73.5)	£1,300.00	£43,108.85	£56,707.10	
Fabric First Approach	**6. Thermal Bridging calculations**			**B (84)**	41.3 (45.5)	£1,000.00	£44,108.85	£58,022.54	
HVAC	**7. Ventilation**	**Upgrades**		**CMEV**	**MVHR**	£4,560.00	£48,668.85	£64,020.96	£5,152.80
HVAC		Results	EPC rating	**B (84)**	**B (84)**				
HVAC		Results	Energy demand kWh/m^2/yr	41.4 (45.5)	30.6 (33.7)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**		**GSHP**	**GSHP**	£11,039.65	£59,708.50	£78,542.95	£12,894.31
HVAC		Results	EPC rating	**C (77)**	**C (77)**				
HVAC		Results	Energy demand kWh/m^2/yr	38.9 (42.8)	30.6 (33.7)				
Further Fabric	**9. Floor Insulation**	**Upgrades**		**Floor insulation**	**Floor insulation**	£0.00	£59,708.50	£78,542.95	£0.00
Further Fabric		Results	EPC rating	N/A	N/A				
Further Fabric		Results	Energy demand kWh/m^2/yr	N/A	N/A				
Renewable Technology	**10. Photovoltaics**	**Upgrades**		**PV**	**PV**	£8,797.50	£68,506.00	£90,115.53	£10,134.72
Renewable Technology		Results	EPC rating	**B (86)**	**B (86)**				
Renewable Technology		Results	kWp	3.7	3.5				
Renewable Technology		Results	Energy demand kWh/m^2/yr	38.9 (42.8)	30.6 (33.7)				

Contingency @ 5%	£3,425.30	£71,931.30
Subtotal		**£71,931.30**
Prelims @ 16%	£11,509.01	£83,440.31
OH&P @ 8%	£6,675.22	£90,115.53
Total £		**£90,115.53**



Notes

Roof top-up insulation has been priced as insulation only and would only be done as part of roof covering replacement under planned works as part of MTIP. The relacement of cavity wall insulation is only partial to end flanks of units. The units are modelled using GSHP with water to water heat pumps and heat store but this requires available external area for boreholes or ground loops. There is potential to use high efficiency electric heating with air to water heat pumps for hot water (fig 45). This modelling is theoretical and each block will be different. The works to this block would likely be carried out as part of a strategic asset management plan.

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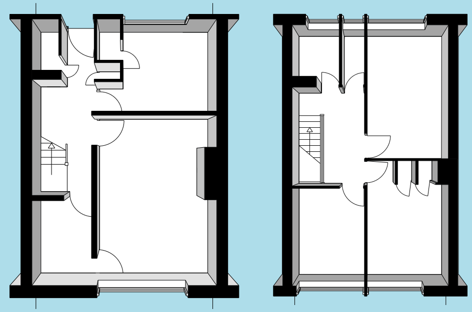
Archetype 14 1976-1982 upper maisonette, cavity and panel wall - 78.0m²

	Upgrades		Results: EPC rating (SAP score)	Results: Space heating demand kWh/m²/yr SAP (PHPP) values	Total £	Cumulative Total £	Cumulative Total inc. OH&P, Prelims	WLC £ (60 year life span)
	Existing		D (68)	134.3 (147.7)				
Fabric First Approach	**1. Top up roof insulation to 400mm**		C (70)	118.5 (130.3)	£1,282.10		£1,686.53	£1,423.14
Fabric First Approach	**2. Thermal bridge rectification works**		C (71)	112.9 (124.2)	£5,500.00	£6,782.10	£8,921.45	£6,105.00
Fabric First Approach	**3. Panelised wall façade & window**		C (78)	74.6 (82)	£11,885.60	£18,667.70	£24,556.25	£13,193.02
Fabric First Approach	**4. Double glazing**		C (80)	65 (71.5)	£6,187.41	£24,855.12	£32,695.41	£6,868.03
Fabric First Approach	**5. Air tightness measures**		B (82)	50.9 (56)	£1,300.00	£26,155.12	£34,405.49	
Fabric First Approach	**6. Thermal Bridging calculations**		B (84)	35.9 (39.5)	£1,000.00	£27,155.12	£35,720.93	
HVAC	**7. Ventilation**	**Upgrades**	**CMEV**	**MVHR**	£4,514.53	£31,669.65	£41,659.52	£5,101.42
		Results – EPC rating	B (84)	B (84)				
		Results – Energy demand kWh/m²/yr	33 (36.3)	26.1 (28.7)				
HVAC	**8. Low Carbon Heat Source**	**Upgrades**	**ASHP**	**ASHP**	£10,471.68	£42,141.33	£55,434.39	£12,115.73
		Results – EPC rating	B (85)	B (86)				
		Results – Energy demand kWh/m²/yr	32.4 (35.7)	25.8 (28.4)				
Further Fabric	**9. Floor Insulation**	**Upgrades**	**Floor insulation**	**Floor insulation**	£10,170.07	£52,311.39	£68,812.50	£11,492.18
		Results – EPC rating	B (86)	B (86)				
		Results – Energy demand kWh/m²/yr	30.6 (33.7)	24 (26.4)				
Renewable Technology	**10. Photovoltaics**	**Upgrades**	**PV**	**PV**	£4,398.75	£56,710.14	£74,598.79	£5,067.36
		Results – EPC rating	A (93)	A (94)				
		Results – kWp	1.8	1.6				
		Results – Energy demand kWh/m²/yr	30.6 (33.7)	24 (26.4)				

Contingency @ 5%	£2,835.51	£59,545.65
Subtotal		**£59,545.65**
Prelims @ 16%	£9,527.30	£69,072.96
OH&P @ 8%	£5,525.84	£74,598.79
Total £		**£74,598.79**



Notes

Roof top-up insulation has been priced as insulation only and would only be done as part of roof replacement under planned works as part of MTIP. Any insulation of voids within brickwork skin to concrete frame and to underside of bedroom above pedway is included in thermal bridge rectification. Panellised wall façade and window cost does not allow for removal and/or replacement of kitchen or other fittings abutting façade. Air tightness measures likely to be minimal. Location of ASHP condenser unit subject to space and planning constraints. Wider opportunity for communal system or heat network.

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