Islington Retrofit Typology Study Summary

Contents

Introduction

This is a summary by Islington Council of a more comprehensive technical study produced by Bioregional, the 'Islington Retrofit Typology Study', which has informed the Retrofit Handbook.

The Bioregional Study outlines a number of retrofit scenarios, a step-by-step process as to how the retrofit scenarios were established, and subsequent impact on energy performance. Individual retrofit measures and works packages have been costed to provide a level of clarity on the financial implications of each pathway.

Developed in collaboration with Transition by Design and Core Five, the Study brings together PAS 2035 certified retrofit coordinators, Passivhaus certified designers and expert cost modellers, with a view to delivering an accurate appraisal of costs, risks and technical challenges of retrofitting the diverse portfolio of housing typologies within Islington.

Split into four key sections, the report looks at the following typologies common to the borough:

- Georgian House (Conservation area)
- Victorian House (Conservation area)
- Early 20th Century Flat
- Mid-20th Century House

For each typology a number of individual measures, appropriate to that typology have been set out, including details relating to the scope of installation works and considerations that should be made as part of its specification to ensure optimum performance.

A number of scenarios have been established for each of the typologies, including detail on technical considerations, heritage consideration where applicable and sequencing to promote the most effective grouping of activities.

The three scenarios explored are:

- Scenario 1: DIY retrofit measures
- Scenario 2: Phased retrofit - achieving deep decarbonisation as cheaply as simply as possible
- Scenario 3: Whole-house retrofit - appropriate for a whole home refurbishment and renovation project

This summary sets out the key findings of the Bioregional Study, to support residents to find the relevant information for their housing typology at a glance.

Methodology

An initial survey of the borough identified four broad phases of development, which are reflected in the corresponding housing typologies: Georgian, Victorian, Early 20th Century and Mid-20th Century.

For each of the selected house typologies, the Bioregional Study covers the following topics:

- **Key features** – Captures background information on the typical home within the typology
- **Baseline review** - Reviews baseline home performance and the sources of heat loss for each typology.
- **Evaluation -** Evaluates the compatible retrofit measures through a bespoke evaluation matrix to form recommendations for home-owners.
- **Scenarios** - Three different retrofit scenarios were identified as part of the study, with tables providing a high-level summary of the individual elements and costings as well as key performance statistics associated with each level of retrofit.

Energy modelling

Operational energy calculations captured within the study have been carried out using Passive House Planning Package (PHPP), utilising the specialist retrofit functions within EnerPHit modelling.

The Passivhaus modelling approach includes both regulated and unregulated energy use to provide a detailed and accurate assessment of energy impacts for each of the retrofit work packages.

The calculation of heat losses and gains to a property requires some assumptions of the average internal temperature of the property. This is the biggest source of uncertainty in any energy modelling calculation, as different occupants can heat their homes under different time schedules and to different target temperatures.

To provide a comparable approach, all typologies have been analysed assuming the occupants heat their homes at a temperature of 21° C for a morning period between 06:00 and 09:00, and in the evenings from 16:00 to 21:00.

Cost modelling

The costs were developed to an Autumn 2023 base date with no allowance for inflation. All costings have been developed using industry databases, current market rates from active projects and market testing on bespoke products. The costs are regionally specific to Islington.

All properties are assumed to be in good condition, and no contingencies are allowed for repair, refurbishment or any remedial works which may be required - other than the making good of any works required for the retrofit measure installation.

In practice, costs will vary on individual buildings depending on the contractors' quoting and perceived difficulty/risk of the task undertaken. It is recommended to get three quotes for any work and understand the contractors' cost basis before proceeding. The cheapest quote may not be the best.

Evaluation framework

The purpose of this framework is to guide residents through the prioritisation of retrofit measures within their home, and to provide specific guidance on the expected benefits and potential drawbacks of installing the different measures.

Evaluation criteria

Each measure was assessed against the following criteria providing a holistic approach to evaluating buildings:

- **Overall energy demand and carbon emission reductions** - The most common heating fuel across Islington is gas (66.5% of properties), utilised within gas boilers, which have been used as the baseline within all the typologies analysed. There are two approaches to reducing energy demand and carbon emissions – reducing the heating and hot water demands (commonly termed "energy efficiency") and switching to higher efficiency heating systems which run off a cleaner fuel ("low carbon technologies,").
- **Cost of installation -** Low-cost measures are under £1,000 to install and are considered potentially affordable to many tenants and homeowners. Medium cost measures are between £1,000 and £15,000, reflecting a mid-range expenditure for a homeowner undergoing moderate renovations. High-cost measures over £15,000 will likely only be installed by home-owners undergoing significant renovation works.

- **Cost-benefit of retrofit measure -**The cost-benefit of retrofit measures has been evaluated based on the economic payback to the occupant. The energy demand reductions have been valued based on current standard utility prices, and straight payback periods calculated based on the installation costs. The cost benefits have been categorised in three bands: short payback measures (<2 years); medium payback (2-10 years); long payback (10+ years).
- **Health and wellbeing impact on occupants -**There are severe health impacts deriving from excess cold and damp in properties, which are closely related to fuel poverty and home energy efficiency. Scenarios were developed to balance installation and running costs of measures with cost savings where possible. For many fuel-poor homes, grant funding is available to mitigate installation costs to the occupant.
- **Disruption of measure installation -** This is based on a qualitative assessment of the impact on occupants' normal daily life. The evaluation scale consists of: Low disruption – less than a day disruption to standard occupation; Medium disruption – requires moderate change to living practices for a small number of days; Major disruption – significant change to living practices for several days.
- **Acoustic impacts -**The acoustic impacts of measures have been evaluated on a neutral or positive comparative basis. Improved glazing performance will improve the acoustic separation of the home from noise pollution, improving occupant wellbeing. The ultimate acoustic impact of a modern heat pump is small, and hence these measures are not ranked as causing additional acoustic pollution, providing they are correctly installed.
- **Heritage and visual impact considerations -**. Measures are ranked based on their impact on external heritage visual impact. The evaluation bands are: Low/no impact - e.g. loft insultation; Medium impacts –e.g. double glazing and heat pumps; High impact – e.g. external wall glazing on street facing façade, triple glazing, solar panels on street facing roof.
- **Local Plan policies -**The Islington Local Plan policies from the September 2023 Strategic and Development Management Policies had an important role in shaping the scope and aim of the Bioregional Study. The purpose of the document is to inform guidance relating to the implementation of specific policies within this plan. The Local Plan policies have acted as an overarching frame to guide the development of the evaluation framework above.

Retrofit scenarios

Three scenarios have been developed for each of the Islington housing typologies to reflect the different starting points and bases from which residents might approach retrofit:

- **DIY retrofit** - aimed at tenants, leaseholders and freeholders with limited financial means to invest in retrofit measures, but a desire to improve the energy efficiency and comfort of their home.
- **Phased retrofit** - aimed at leaseholders and freeholders who are looking to decarbonise their homes and improve energy efficiency, but are looking to achieve this at minimal cost and disruption. The following phases are developed:

1. High-value energy efficiency - Before replacing heating systems, attempts should be made to improve the energy efficiency of homes, in particular the worst performing elements. These measures provide large energy savings for the capital investment.
2. Electrification and decarbonisation - The next phase is to remove fossil fuel powered systems from the property, replacing boilers and gas hobs where possible, and installing low-carbon generation if possible.
3. Further measures - The final phase is to improve the un-retrofitted building elements naturally through the building life-cycle. These measures are more costly.

- **Whole House Retrofit -** aimed at leaseholders and freeholders who are undertaking a thorough home refurbishment. The retrofit is proposed under a fabric first process, significantly improving energy efficiency, and decarbonising the property in a single phase of works.

Overall considerations

Homeowners are encouraged to approach retrofit from a holistic perspective.. In particular, before undertaking any energy efficiency measure it is recommended to consider the following questions:

- **How is my home ventilated?**

Before undertaking any energy efficiency measures, it is necessary to consider how this will impact on the flow of air through the property, as this could potentially create a risk of condensation and mould.

- **How does this measure impact on other measures I want to do?**

In retrofit, some measures complement each other -sometimes to the extent where there is a significant benefit in doing them at the same time. But occasionally, measures may impact on other measures, and the interplay between them needs to be paid careful attention.

- **What will the impact be on comfort within the home?**

Energy efficiency measures keep heat in, both when it is cold outside and also when it is hot. If an insulated home receives excessive heat gains during summer - either from activities within the home, or from sunlight, it can become extremely uncomfortable. If this is a concern, homeowners need to think about measures such as closing shutters or using ventilation and extraction systems.

Georgian typology

Key features

Figure 1 - Georgian typology facade

Typically formed of terraced and semi-detached properties, Georgian homes were built from early 1700 - 1840. Georgian properties are characterised by their grand proportions, including large rooms and large windows, providing good daylight. Homes were mostly arranged over three or four storeys, often with small dormer style windows at the top floor. Timber sash windows are common on these homes. In Islington, these properties are often Listed and located within Conservation areas.

- **Roof** – Insulation can improve the thermal performance of the roof, however without considering the need for ventilation, it can have unintended consequences through increased risk in mould growth.
- **Chimney** – Working fireplaces and brick chimneys contribute to air leaks. Heritage considerations would not allow the removal of chimney flues; however they can be blocked to help reduce heat losses.
- **Windows** – There are limitations to the replacement of existing single glazed sash windows. Replacement windows would have to be in keeping with the existing character, or where this isn't possible secondary glazing can be an option.
- **Internal floor/ceilings** – These have been designed to allow ventilation and prevent dry and wet rot and woodworm. Any insultation would have to consider these principles to avoid unintended consequences.
- **Ground floor** - Some homes have stucco or clay flooring, or Portland or similarly coloured stone, which are challenging to insulate. Options exist to replace with an updated limecrete slab.
- **Street facing external walls** - Change of appearance is limited, so potential retrofit options for these solid walls is restricted. Use of internal wall insulation provides a solution that does not impact the appearance of the façade.

Baseline information

Table 1 - Georgian typology Fabric performance pre-retrofit

Envelope element	Performance characteristics (W/m2.K)
External wall	1.20
Roof/top floor ceiling	3.00
Floor slab/basement ceiling	0.47
Thermal bridge coefficient (W/(m.K))	0.10
Glazing (U-value)	4.32
Glazing (g-value)	0.83

Table 2 - Georgian typology Energy performance pre-retrofit

Metric		Units
Annual heat demand	181.3	kWh/(m2a)
Peak heating load	13.5	kW
Emissions rate	6,983	KgCo2, annum

Carbon saving over baseline	-	%
EUI (regulated and unregulated)	245.6	kWh/(m2a)
Estimated annual running costs – standard tariff	2,325	(£/year)

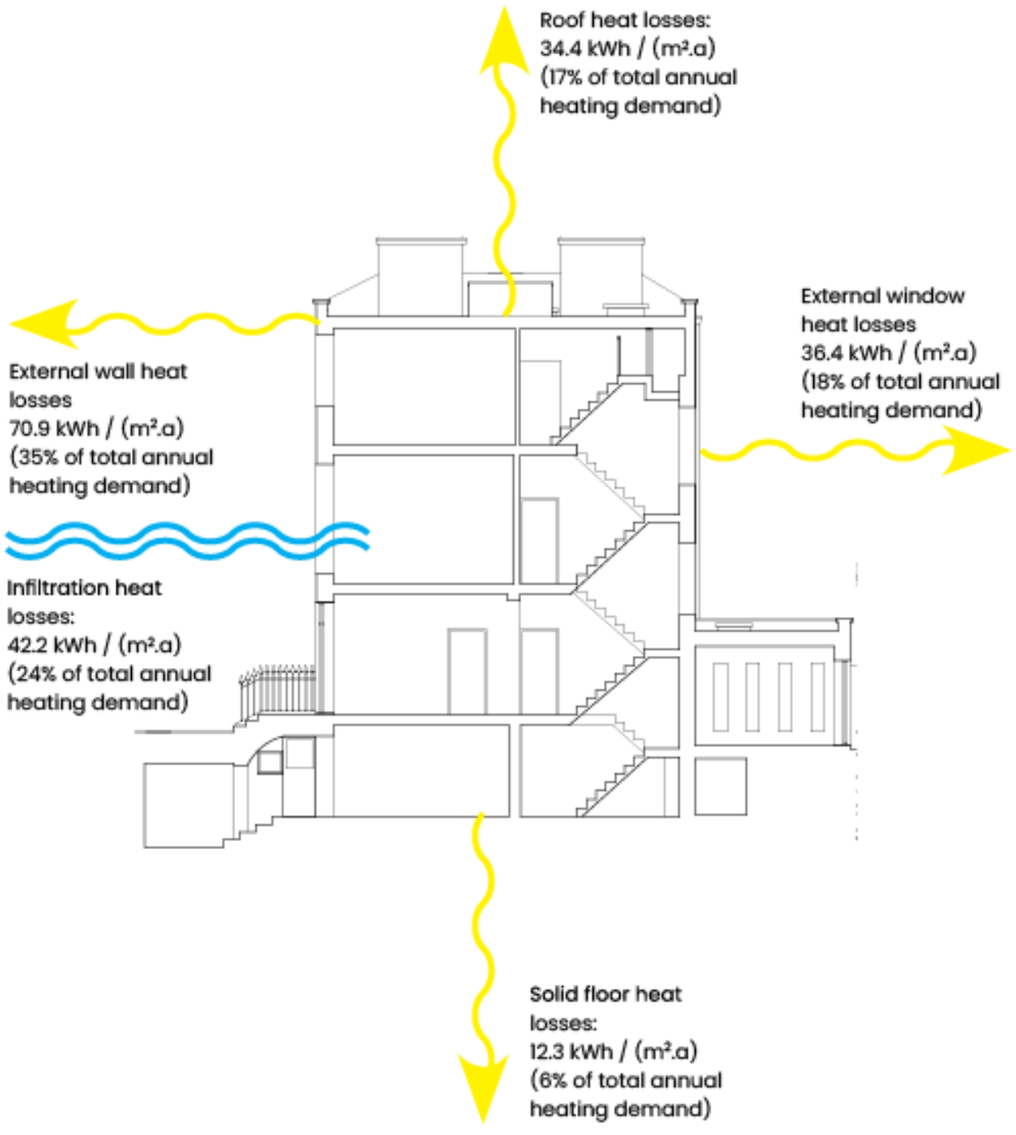


Figure 2 - Georgian typology heat loss diagram

Evaluation

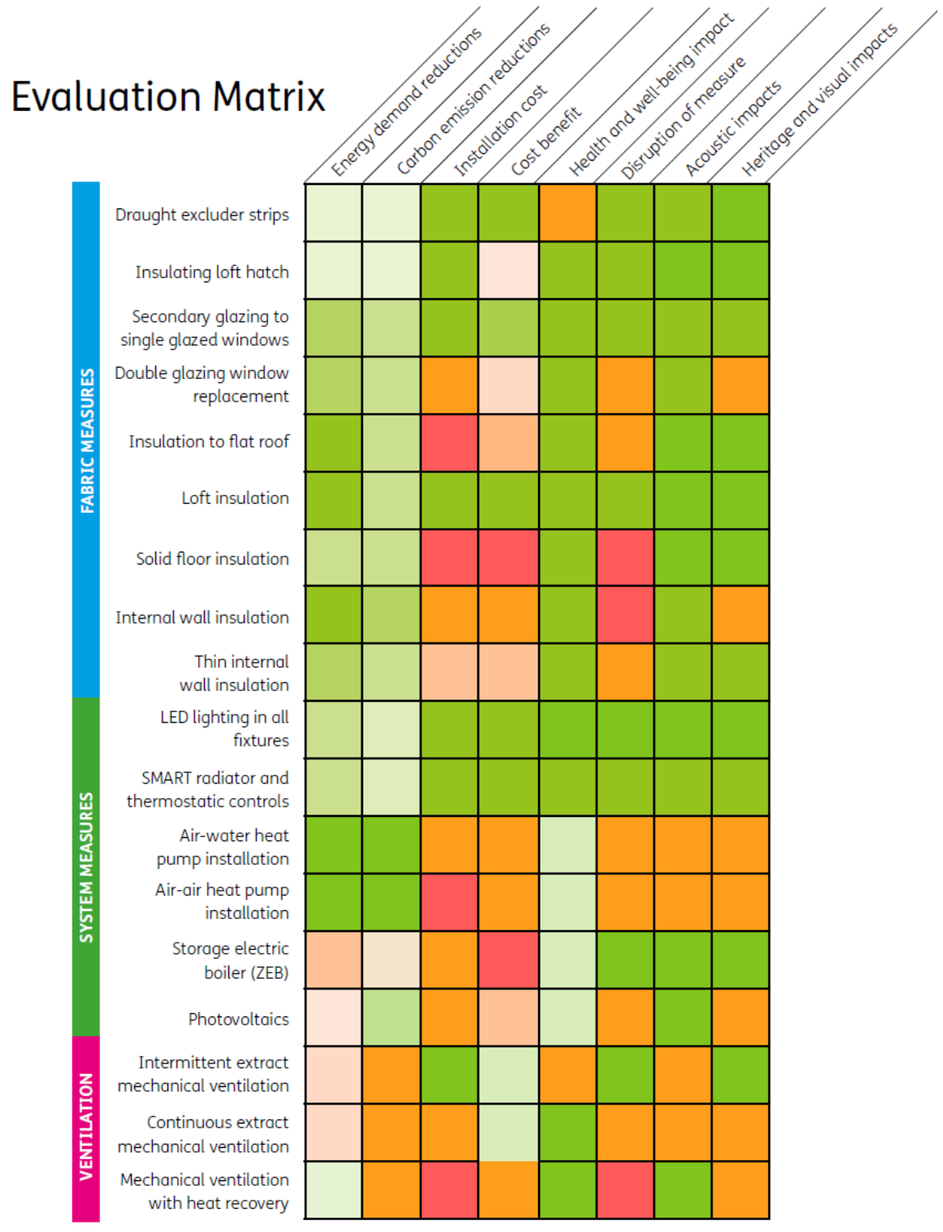


Figure 3 - Georgian typology evaluation matrix

Table 3 – Georgian typology Scenario evaluation

Evaluation criteria	DIY retrofit	Phased retrofit	Whole-house retrofit
Energy and carbon demand reductions:	Energy demand reductions are particularly tricky to estimate, as they are highly dependent on the existing condition and installation quality.	This scenario prioritises high-value energy demand reductions, and deep carbon reductions through heat-pump installation as early in the process as possible	Carbon emission reductions of 90% can be achieved through this scenario compared to the baseline building
Installation cost	Lower end estimates represent basic products with no aesthetic sensitivity, higher end costs reflect more premium products fitting into current building elements sensitively	Same as for DIY measures.	Same as for DIY measures.
Heritage	DIY measures tend to be less intrusive and therefore are impacted less by heritage constraints, however they can still alter the condition and overall function if they are incorrectly installed	Heritage features have been protected throughout the process. Internal wall insultation is recommended to maintain original elevation appearance, and double-glazed wooden sash windows to maintain character.	Only internal wall insulation is recommended, and triple glazed windows are specified only on the rear façade, to reflect heritage constraints.
Health and wellbeing impacts	Installation of draught proofing around windows and doors provides a low-cost and immediate impact for the occupant	Limited wellbeing benefits are attached to Phases 1 and 2 as the focus is on carbon emission reduction. Phase 3 measures can significantly improve occupant comfort and the internal environment.	Fabric upgrade features will deliver health improvements through increased air tightness and generally improved thermal performance. Significant improvements will be seen through the introduction of the MVHR system - delivering fresh air during winter.
Risks	Any alterations to the home should be considered in the context of its existing operations. Potential unintended consequences include increased air tightness, and the requirements associated with ventilation necessary to reduce the risk of damp and mould	The importance of considering ventilation provision through these measures cannot be overstated. Though limited risks are attached to Phase 1 measures, the deeper lifecycle measures in Phase 3 require a more proactive ventilation response.	Any alterations to the home should be considered in the context of its existing operations and condition. Specification of an MVHR active ventilation system should significantly mitigate the risks from a moisture flow perspective.
Sequencing	DIY measures can be installed in any sequence.	Depending on building lifecycle - some Phase 3 measures may be installed in Phase 1. E.g. if there is an immediate need for window replacement. Heat-pump installation should be prioritised as early as possible in the retrofit journey	Where façade work is undertaken at height, it is advised that other work in similar areas is also carried out to reduce costs, e.g. when renting scaffolding to replace windows, PV installations on the roof should be considered in parallel. Fabric and ventilation measures should be completed before installing heat-pump

Georgian typology - DIY retrofit scenario

Table 4 – Georgian typology DIY retrofit scenario measures

Measure		Energy demand reductions	Carbon emission reductions	Installation cost
LED lighting		5% electricity	~2%	£200- £1500
Insulated loft hatch and surround draught proofing		3% gas	~2%	£300- £500
Air-tightness measures to front and rear doors and windows		5.5% gas	~2%	£300- £800
Heating system controls and monitoring		8% gas	~3%	£400- £1000
Total reductions and overall cost		**11.7% gas ; 5% electricity**	**~6%**	**~£1,200-£3,800**

Georgian typology - Phased retrofit scenario

Table 5 – Georgian typology Phase 1 High-value energy efficiency

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
DIY measures		11.7% gas 5% electricity	~6%	£1,200 - £3,800
Loft insulation		20% gas	~15%	£1,000- £3,000
Secondary glazing		25% gas	~18%	£3,000- £5,000
Total reductions and overall cost		**49% gas ; 5% electricity**	**~30%**	**~£4,000- £8,000**

Table 6 -Georgian typology Phase 2 Electrification and decarbonisation

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
Installation of an ASHP Domestic Hot Water System new cylinder Radiator replacement, for heat pump installation		100% gas + 190% electricity	~75%	£8,000 - £12,000[2]
Roof-mounted solar PV (4kW array)		5% electricity	~5%	£10,000- £16,000

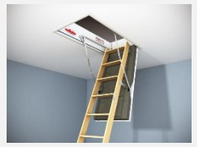
Total reductions and overall cost		**100% gas; 190% electricity**	**~84%**	**~£18,000-£28,000**

Table 7 – Georgian typology Phase 3 Further measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
Double glazed sash windows		5% electricity	~5%	£25,000-£40,000
Internal wall insulation		20% electricity	~20%	£20,000-£40,000
Door replacements		3% electricity	~5%	£5,000-£10,000
Mechanical Ventilation and Heat Recovery (MVHR) installation		5% electricity	~5%	£7,000-£10,000
Total reductions and overall cost		**30% electricity**	**~30%**	**£57,000-£100,000**

Georgian typology - Whole house retrofit

Table 8 – Georgian typology Whole-house retrofit measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
LED lighting		5% electricity	~2%	£200- £1500
Insulated loft hatch		22% gas	~2%	£1,500-£3,500
Double glazed sash (front façade) Triple glazed windows (rear façade) Door replacements		30% gas	~5%	£40,000-£60,000
Internal wall insulation		25% gas	~5%	£20,000-£40,000
MVHR installation		5% gas	~5%	£5,000-£7,000
New air-to-water ASHP DHWS - new cylinder with future solar integration		100% gas ; 120% electricity	~80%	£6,000-£10,000[3]
Roof-mounted PV (8kW array)		5% electricity	~5%	£14,000-£19,000
Total reduction and overall cost		**110% electricity ; 100% gas**	**~89%**	**~£86,000-£140,000**

Retrofit scenarios performance statistics

Table 9 - Georgian typology DIY retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	160	kWh/(m2a)	11.%
Peak heating load	11.8	kW	12.5%
Emissions rate	6,537	KgCo2, annum	6.4%
EUI (regulated and unregulated)	286	kWh/(m2a)	6.3%
Estimated annual running costs – standard tariff	£1,900	(£/year)	18%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	11	kg.CO2/m2	-

Table 10 - Georgian typology phased retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	93.8	kWh/(m2a)	49%
Peak heating load	6.25	kW	54%
Emissions rate	1,149	KgCo2, annum	84%
EUI (regulated and unregulated)	50.9	kWh/(m2a)	79%
Estimated annual running costs – standard tariff	£1,820	(£/year)	21.6%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	298	kg.CO2/m2	-

Table 11 - Georgian typology whole-house retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	68,8	kWh/(m2a)	62%
Peak heating load	4.5	kW	66%
Emissions rate	746	KgCo2, annum	89%
EUI (regulated and unregulated)	38.9	kWh/(m2a)	84%
Estimated annual running costs – standard tariff	£1,340	(£/year)	42%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	341	kg.CO2/m2	-

Victorian typology

Key features

Figure 4 - Victorian typology facade

Typically formed of terraced properties, Victorian homes were built from around 1840 - 1900. Built of solid brick walls, Victorian houses often had slate roofs and terracotta ridge tiles. This period also saw the introduction of plate glass and introduction of bay and sash window. Victorian properties re-introduced high pitched roofs, with top floor rooms in the eaves. Many of these homes are now located within Conservation Areas across the borough. Early homes from the period generally have listed building status.

- **Roof -** Care should be taken when installing top-up roof insulation to ensure ventilation provision is maintained and risk of in condensation and mould growth is not increased. For homes within a conservation area or with listed building status, roof upgrades will be restricted in reference to the surroundings.
- **Chimney -** Whilst removal of flues will not be possible due to the visual impact on the property, it is possible to block them to reduce the air leakage.
- **Windows -** Limitations around replacement options given conservation area restrictions. Replacement windows must be in-keeping with existing characteristics. Potential for application of secondary glazing where full replacement is not feasible.
- **Internal floor/ceiling -** Designed at the time to allow ventilation and prevent issues of dry and wet rot and woodworm. A typical suspended floor from the period consisted of a series of joints supported by external and internal load-bearing walls and covered by floorboards.
- **Street facing external walls -** For street facing walls, change of appearance is generally limited due to either listing or location within conservation area. Potential retrofit options for these solid walls is restricted. Use of internal wall insulation provides a solution that does not impact the appearance of the façade

Baseline information

Table 12 - Victorian typology fabric performance pre-retrofit

Envelope element	Performance characteristics (W/m2.K)
Opaque elements	
External wall	1.36
Roof/top floor ceiling	0.49
Floor slab/basement ceiling	1.19
Thermal bridge coefficient (W/(m.K))	0.21 (Average)
Windows/Doors/Shading systems	
Glazing (U-value)	4.45
Glazing (g-value)	0.86

Table 13 - Victorian typology energy performance pre-retrofit

Metric		Units
Annual heat demand	145.1	kWh/(m2a)
Peak heating load	8.8	kW
Emissions rate	5,590	KgCo2, annum
Carbon saving over baseline	-	%
EUI (regulated and unregulated)	215.9	kWh/(m2a)
Estimated annual running costs – standard tariff	1,752	(£/year)

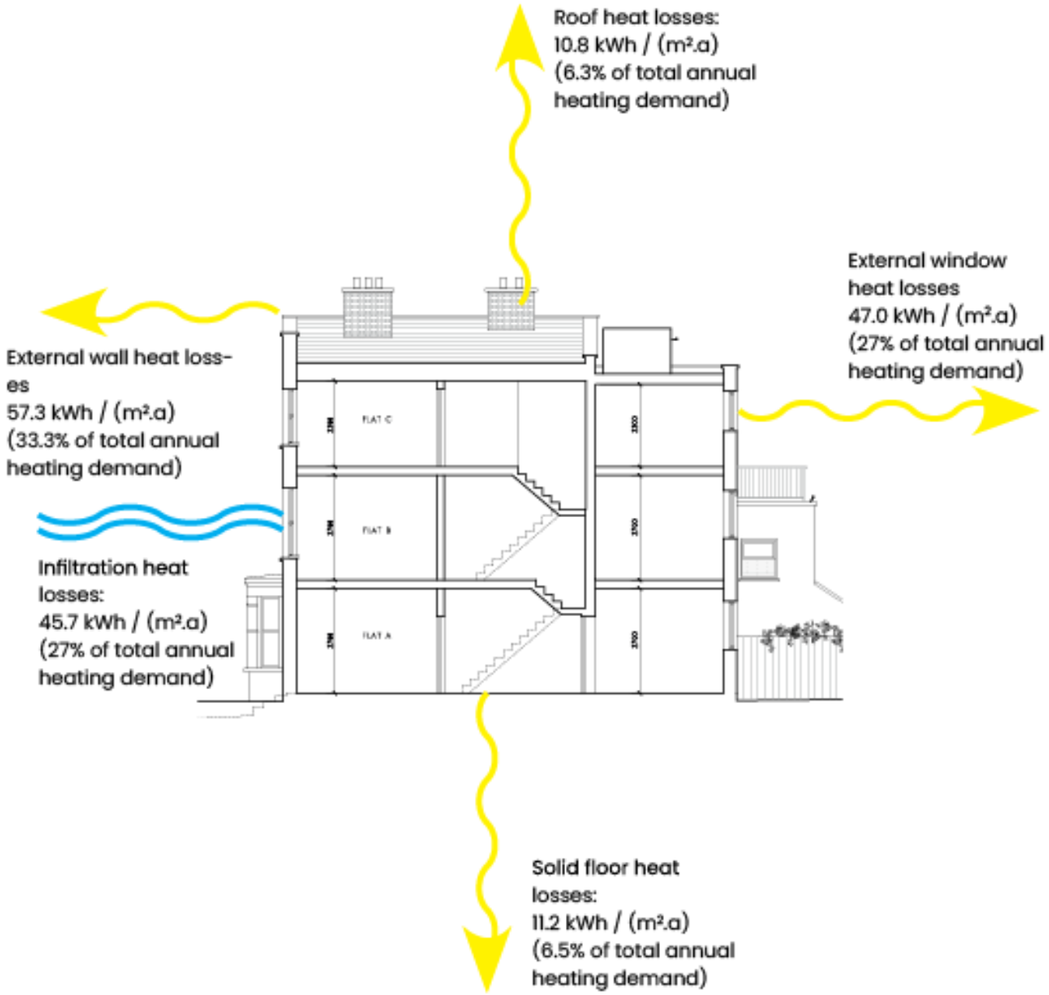


Figure 5 - Victorian typology heat loss diagram

Evaluation

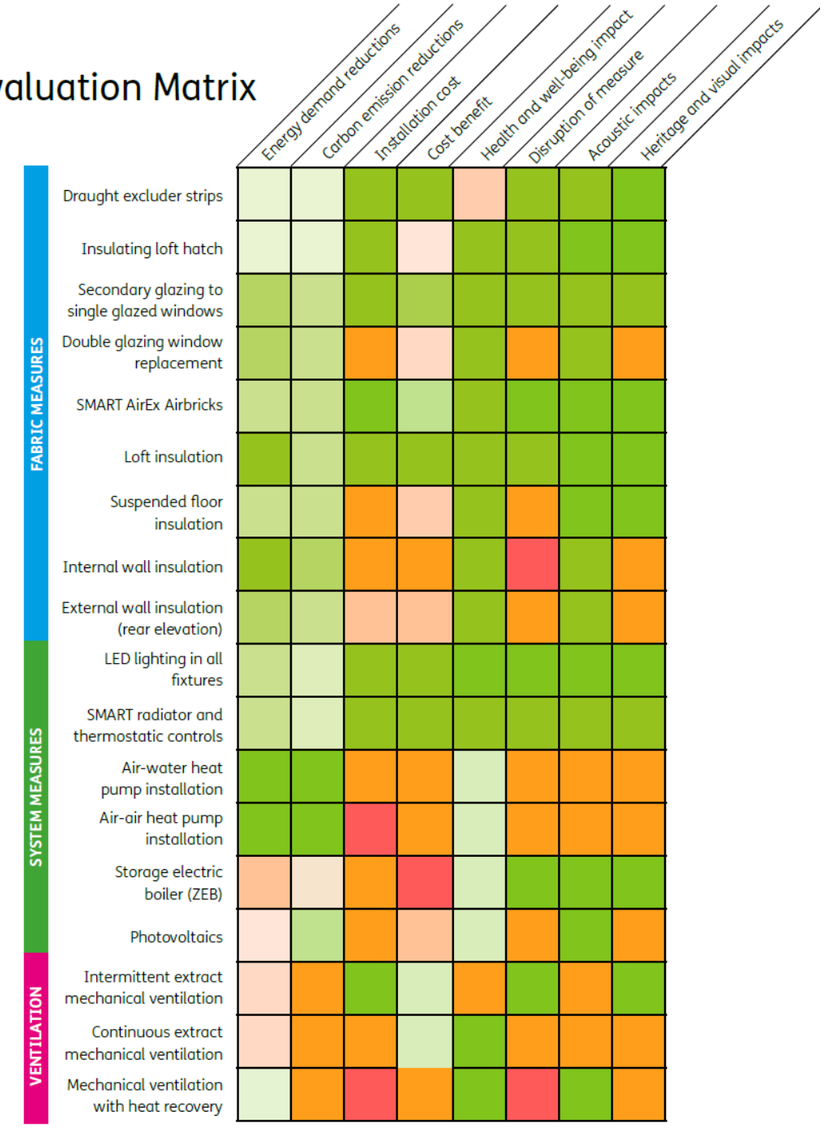


Figure 6 - Victorian typology evaluation matrix

Table 14 - Victoria typology scenario evaluation

Evaluation criteria	DIY retrofit	Phased retrofit	Whole-house retrofit
Energy and carbon demand reductions:	For DIY measures, energy demand reductions are particularly tricky to estimate, as they are highly dependent on existing building element condition and installation quality	This scenario prioritises high-value energy demand reductions, and deep carbon reductions through heat-pump installation as early in the process as possible	Carbon emission reductions of 90% can be achieved through this scenario compared to the baseline building
Installation cost	Lower end estimates represent basic products with no aesthetic sensitivity, higher end costs reflect more premium products fitting into current building elements sensitively	Same as for DIY measures.	Same as for DIY measures.
Heritage	DIY measures tend to be less intrusive and therefore are impacted less by heritage constraints, however they can still alter the condition and overall function if they are incorrectly installed	Heritage features have been protected throughout the process. Internal wall insultation is recommended to maintain original elevation appearance, and double-glazed wooden sash windows to maintain character.	Front facade features are preserved, with more intrusive measures on rear facade to achieve higher performance, to take into account heritage constraints
Health and wellbeing impacts	Installation of draught proofing around windows and doors provides a low-cost and immediate impact for the occupant	Limited wellbeing benefits are attached to Phases 1 and 2 as the focus is on carbon emission reduction. Phase 3 measures can significantly improve occupant comfort and the internal environment.	Fabric upgrade features will deliver health improvements through increased air tightness and generally improved thermal performance. Significant improvements will be seen through the introduction of the MVHR system - delivering fresh air during winter.
Risks	Any alterations to the home should be considered in the context of its existing operations. Potential unintended consequences include increased air tightness, and the requirements associated with ventilation necessary to reduce the risk of damp and mould	The importance of considering ventilation provision through these measures cannot be overstated. Though limited risks are attached to Phase 1 measures, the deeper lifecycle measures in Phase 3 require a more proactive ventilation response.	Any alterations to the home should be considered in the context of its existing operations and condition. Specification of an MVHR active ventilation system should significantly mitigate the risks from a moisture flow perspective.
Sequencing	DIY measures can be installed in any sequence.	Depending on building lifecycle - some Phase 3 measures may be installed in Phase 1. E.g. if there is an immediate need for window replacement. Heat-pump installation should be prioritised as early as possible in the retrofit journey	It is recommended to install rear facade EWI, glazing and PV systems utilising the same scaffolding to deliver a construction saving. Installing HP and MVHR at the same time is also advised to ensure service junctions through new EWI is developed within the design. QBoT and internal wall insulation could be performed at the same time, to ensure joist protection and limit internal disruption

Victorian typology - DIY retrofit scenario

Table 15 - Victorian typology DIY retrofit measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
LED lighting		4% electricity	~2%	£150-£1000
Insulated loft hatch		2% gas	~2%	£300- £500
Draught proofing windows and doors		4% gas	~2%	£250- £600
Heating system controls and monitoring		4% gas	~3%	£400- £1000
Total reductions and overall cost		**7% gas** **4% electricity**	**~5%**	**~£1,100-£3,100**

Victorian typology - Phased retrofit scenario

Table 16 - Victorian typology Phase 1 High value energy efficiency measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
DIY measures		7% gas 4% electricity	~5%	£1,100 - £3,100
Upgraded loft insulation		8% gas	~15%	£1,000-£3,000
Secondary glazing		31% gas	~18%	£1,500-£2,600
AirEx SMART airbricks		12%	~18%	£1,000-£2,000
Total reductions and overall cost		49% gas 5% electricity	~30%	~£4,600-£10,000

Table 17 - Victorian typology - Phase 2 Electrification and decarbonisation

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
Installation of an ASHP with cylinder DHWS specification of a new cylinder Radiator replacement, resized for HP installation		100% gas 132% electricity	~75%	£7,000 - £10,000[4]
Roof-mounted PV (4kW array)		7% electricity	~5%	£10,000-£16,000
Total reductions and overall cost		**100% gas** **132% electricity**	**~84%**	**~£17,000-£26,000**

Table 18 - Victorian typology Phase 3 Further measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
Double glazed sash windows		5% electricity	~5%	£20,000-£24,000
Internal wall insulation (front façade)		10% electricity	~10%	£8,000-£16,000
External wall insulation (rear façade)		12%	~12%	£6,000-£10,000
Door replacements		3% electricity	~5%	£2,000-£4,000
Mechanical Ventilation and Heat Recovery installation		5%	~5%	£7,000-£10,000
Total reductions and overall cost		**27% electricity**	**~27%**	**~£35,000-£56,000**

Victorian typology - Whole-house retrofit scenario

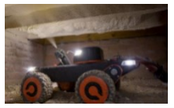
Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
LED lighting		4% electricity	~2%	£150- £1000
Upgraded insulated loft hatch		10% gas	~8%	£1,500-£3,500
Double glazed sash (front façade) Triple glazed windows (rear façade) Door replacements		20% gas	~16%	£25,000-£35,000
Internal and external wall insulation		25% gas	~20%	£14,000-£26,000
QBoT underfloor insultation		6% gas	~4%	£6,000-£8,000
MVHR installation		5% gas	~5%	£5,000-£7,000
New air-to-water ASHP DHWS - new cylinder with future solar integration		100% gas 83% electricity	~80%	£5,000-£8,000[5]
Roof-mounted PV (8kW array)		7% electricity	~5%	£14,000-£19,000
Total reductions and overall cost		**76% electricity; 100% gas**	**~89%**	**£70,000-£107,000**

Table 19 - Victorian typology whole-house retrofit measures

Retrofit scenarios performance statistics

Table 20 - Victorian typology DIY retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	134.9	kWh/(m2a)	7.0%
Peak heating load	8.1	kW	8.0%
Emissions rate	5,280	KgCo2, annum	5.5%
EUI (regulated and unregulated)	209.6	kWh/(m2a)	2.9%
Estimated annual running costs – standard tariff	£1,675	(£/year)	4.4%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	13	kg.CO2/m2	-

Table 21 - Victorian typology Phased retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	85.4	kWh/(m2a)	41%
Peak heating load	5.9	kW	33%
Emissions rate	1,078	KgCo2, annum	81%
EUI (regulated and unregulated)	53.5	kWh/(m2a)	75%
Estimated annual running costs – standard tariff	£1,500	(£/year)	14%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	168	kg.CO2/m2	-

Table 22 - Victorian typology whole-house retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	50.4	kWh/(m2a)	65%
Peak heating load	3.4	kW	62%
Emissions rate	636.2	KgCo2, annum	89%
EUI (regulated and unregulated)	38.7	kWh/(m2a)	82%
Estimated annual running costs – standard tariff	£1,150	(£/year)	35%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	201	kg.CO2/m2	-

Early 20th Century typology

Key features

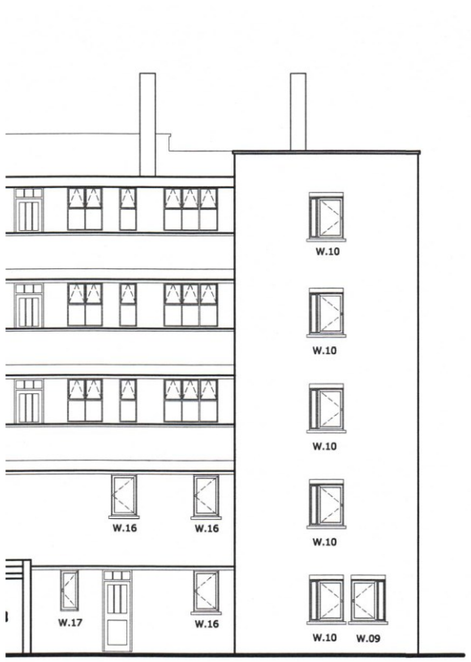


Figure 7 - Early 20th Century facade

Built of solid brick walls, Early 20th century homes were originally specified with single glazed windows, often retrofit with double glazing in recent years. Flats were typically designed with communal outdoors spaces and access. Flats often had a small balcony. Many of these flats will be occupied by tenants, either under social rent, affordable rent or private rental conditions. There is also likely to be a proportion of the flats owned under leasehold terms within the blocks. Different floors of the block will have different priorities. Notably the ground and top floor flats will have significant heat loss impacts of the ground and roof. The summary results provided within each scenario are provided for the mid-floor flats only.

- **Windows -** Homes of the era were often built with timber single glazed windows. Much of the stock has however since been retrofit with improved double glazing, however, many of these upgrades are now very dated and performance levels significantly less than that of products available in today's market.
- **Internal floor/ceiling -** A traditional suspended timber floor, allowing air movement below. An uninsulated ground floor means there is limited comfort in these areas.
- **External walls -** Whilst buildings of this era are typically solid wall construction, external and internal wall insulation products offer a solution where there is not cavity

Baseline information

Table 23- Early 20th Century typology fabric performance pre-retrofit

Envelope element	Performance characteristics (W/m2.K)
External wall	2.50
Roof/top floor ceiling	3.38
Floor slab/basement ceiling	1.20
Thermal bridge coefficient (W/(m.K))	-
Glazing (U-value)	2.60
Glazing (g-value)	0.78

Table 24 - Early 20th Century typology energy performance pre-retrofit

Metric	Ground floor	Middle floor	Top floor	Units
Annual heat demand	177.7	172.4	302.6	kWh/(m2a)
Peak heating load	4.8	4.8	8.2	kW
Emissions rate	3,940	3,837	5,840	KgCo2, annum
EUI (regulated and unregulated)	243.5	237.5	382	kWh/(m2a)
Estimated annual running costs – standard tariff	£1,284	£1,262	£1,710	(£/year)

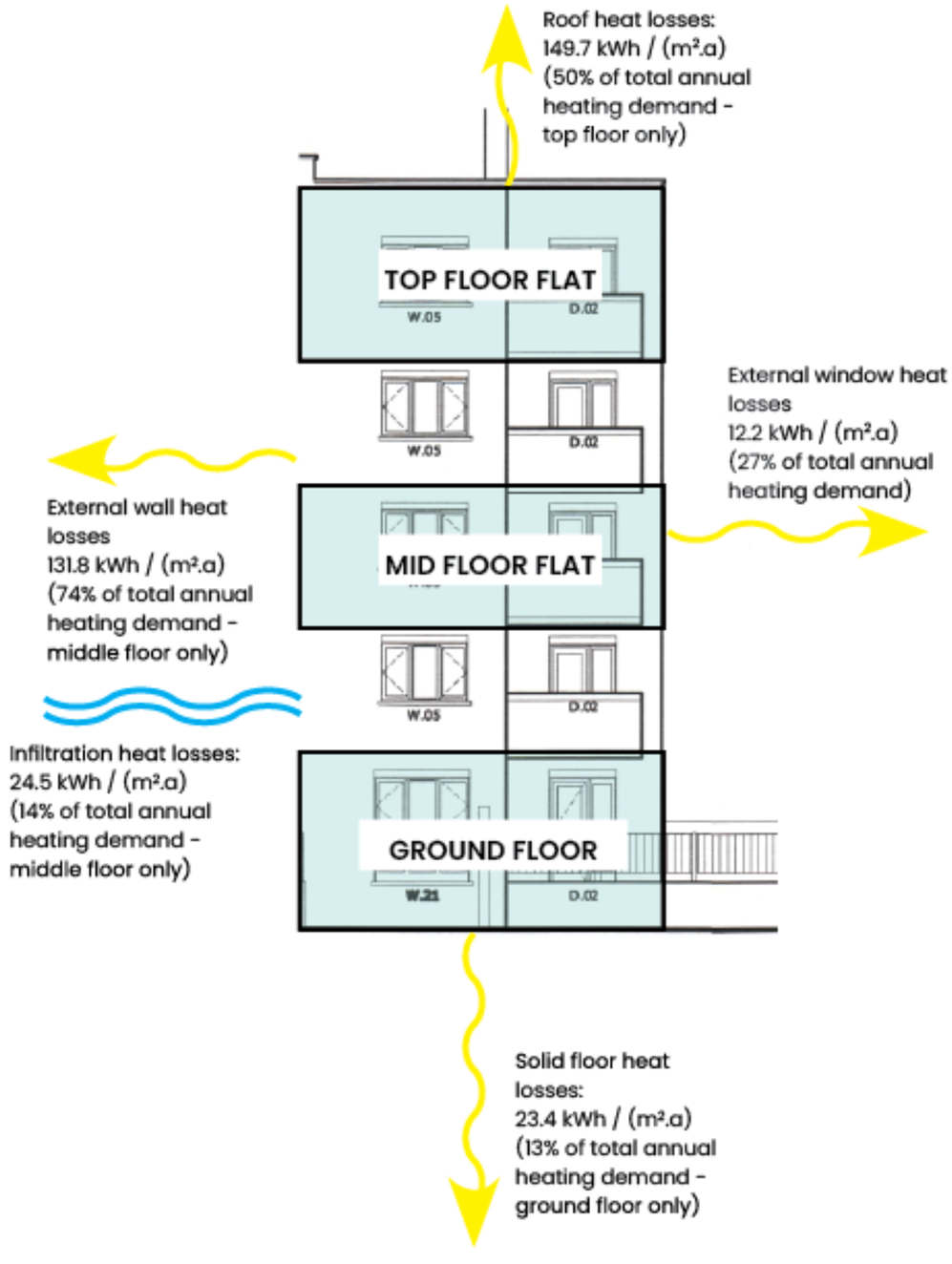


Figure 8 - Early 20th Century heat loss diagram

Evaluation

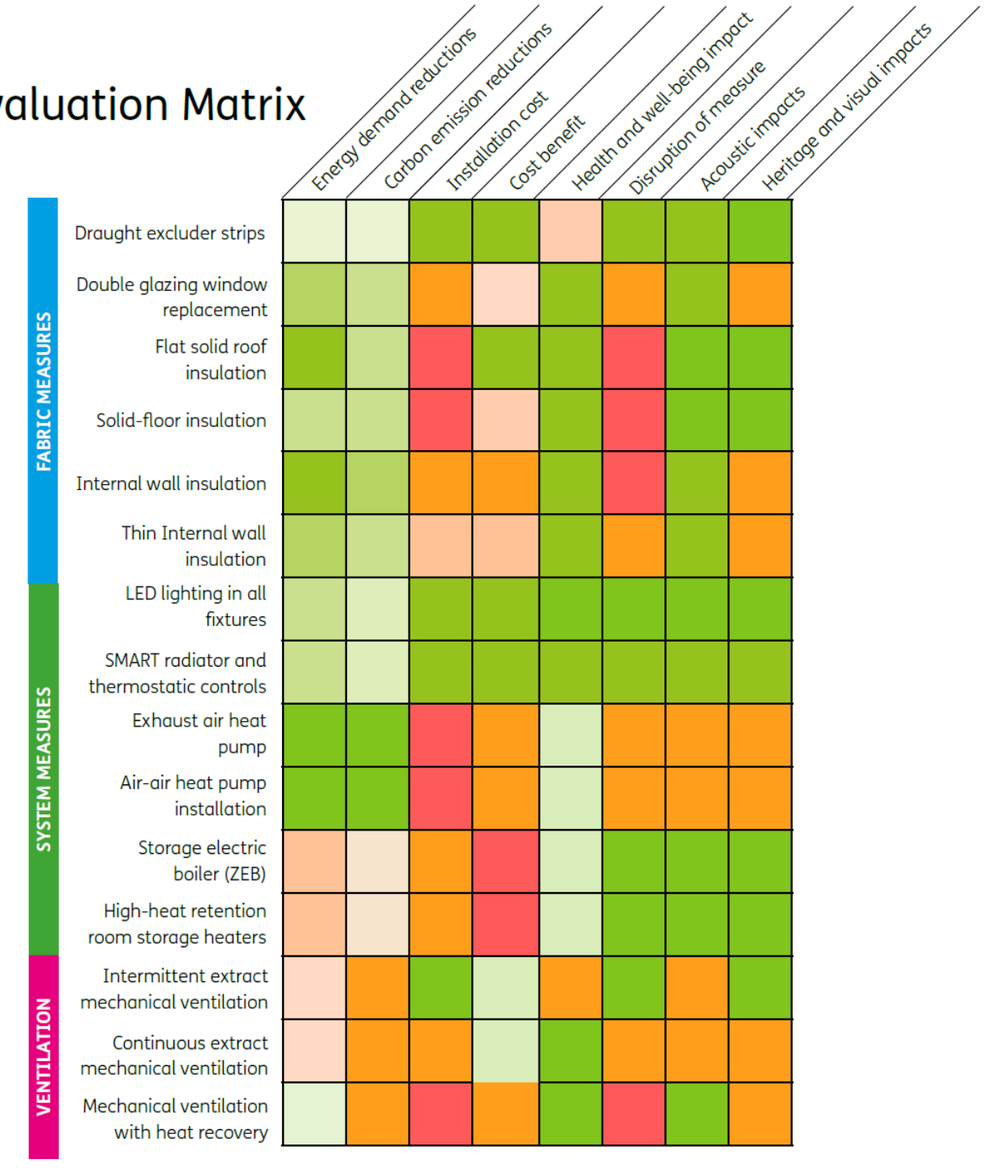


Figure 9 - Early 20th Century evaluation framework

Table 25 - Early 20th Century typology scenario evaluation

Evaluation criteria	DIY retrofit	Phased retrofit	Whole-house retrofit
Energy and carbon demand reductions:	For DIY measures, energy demand reductions are particularly tricky to estimate, as they are highly dependent on existing building element condition and installation quality	This scenario prioritises high-value energy demand reductions, and deep carbon reductions through heat-pump installation as early in the process as possible	Carbon emission reductions of around 80% can be achieved through this scenario compared to the baseline building
Installation cost	Lower end estimates represent basic products with no aesthetic sensitivity, higher end costs reflect more premium products fitting into current building elements sensitively	Same as for DIY measures.	Same as for DIY measures.
Heritage	DIY measures tend to be less intrusive and therefore are impacted less by heritage constraints, however they can still alter the condition and overall function if they are incorrectly installed	Heritage constraints are a less significant element of these properties - but often features of value remain. These could be art deco balcony stylings, or points of interest on facade design. The "through the wall" PTAC units will require grills which should be sensitive to building context. Additionally, freeholders should be made aware of the benefits of these units and have a process for ensuring permissions to leaseholders are not unreasonably withheld.	Recommendations have been made with consideration to heritage constraints.
Health and wellbeing impacts	Installation of draught proofing around windows and doors provides a low-cost and immediate impact for the occupant	Wellbeing benefits are attached to Phases 1 and 2 alongside the focus on pragmatic carbon emission reduction. Aereco and improved bathroom / kitchen extracts will significantly improve ventilation through the property, and should improve wellbeing of residents	Fabric upgrade features will deliver health improvements through increased air tightness and generally improved thermal performance. Significant improvements will be seen through the introduction of the MVHR system - delivering fresh air during winter.
Risks	Any alterations to the home should be considered in the context of its existing operations. Potential unintended consequences include increased air tightness, and the requirements associated with ventilation necessary to reduce the risk of damp and mould	The importance of considering ventilation provision through these measures cannot be overstated. This has been prioritised in Phase 1 due to these risks	Any alterations to the home should be considered in the context of its existing operations and condition. Specification of an MVHR active ventilation system should significantly mitigate the risks from a moisture flow perspective.
Sequencing	DIY measures can be installed in any sequence.	Depending on building lifecycle - some phase 3 measures may be installed in Phase 1. E.g. if there is an immediate need for window replacement. The logic of this scenario is to ensure heat-pump installation is prioritised as early as possible in the retrofit journey.	Simultaneous installation of all measures is recommended for maximum cost savings and to ensure clean interfaces

Early 20th Century typology - DIY retrofit scenario

Table 26 - Early 20th Century DIY retrofit measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
LED lighting		4% electricity	~2%	£80-£200
Draught proofing windows and doors		3% gas	~2%	£50- £200
Heating system controls and monitoring		4% gas	~3%	£400- £1000
Total reductions and overall cost		**6% gas** **2% electricity**	**~5%**	**~£530-£1,400**

Early 20th Century typology - Phased retrofit scenario

Table 27 - Early 20th Century Phase 1 - High value energy efficiency measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
DIY measures		6% gas 2% electricity	~5%	£530 - £1,400
Insulated roof (top floor only)		40% gas	~35%	£3,000-£7,000
AirEx SMART airbricks/ Aereco DCV trickle vents Upgraded extract fans		8%	~8%	£1,000-£3,000
Total reductions and overall cost		**13% gas ; 2% electricity**	**~15%**	**~£4,530-£11,400**

Table 28 - Early 20th Century Phase 2 - Electrification and decarbonisation measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
Packaged terminal HP + radiant panels New high-efficiency DHW cylinder		100% gas 240% electricity	~60%	£8,000 - £14,000

Table 29 - Early 20th Century Phase 3 - Further measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
Double glazed windows		10% electricity	~10%	£8,000-£12,000
Internal wall insulation		41% electricity	~41%	£12,000-£24,000
Door replacements		5% electricity	~5%	£2,000-£4,000
Total reductions and overall cost		51% electricity	~41%	~£22,000-£40,000

Early 20th Century typology – Whole-house retrofit scenario

Table 30 - Early 20th Century typology whole-house retrofit measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
LED lighting		4% electricity	~2%	£80- £200
Double glazed windows		10% gas	~8%	£8,000-£12,000
Internal wall insulation		41% gas	~35%	£12,000-£24,000
Door replacement		5% gas	~4%	£2,000-£4,000
Packaged cabinet MVHR installation + Exhaust air HP + New high efficiency DHW cylinder		100% gas 83% electricity	~80%	£12,000 £20,000[6]
Total reductions and overall cost		**95% electricity** **100% gas**	**~81%**	**~34,000-£60,000**

Retrofit scenarios performance statistics

Table 31 - Early 20th Century DIY retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	163.0	kWh/(m2 a)	5.5%
Peak heating load	4.3	kW	10.4%
Emissions rate	2,890	KgCo2, annum	4.8%
EUI (regulated and unregulated)	226	kWh/(m2 a)	4.8%
Estimated annual running costs – standard tariff	£1,209	(£/year)	4.2%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	18	kg.CO2/m2	-

Table 32 - Early 20th Century Phased retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	150	kWh/(m2a)	13%
Peak heating load	3.4	kW	15%
Emissions rate	1,031	KgCo2, annum	66%
EUI (regulated and unregulated)	75.8	kWh/(m2a)	68%
Estimated annual running costs – standard tariff	£1,287	(£/year)	+2%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	340	kg.CO2/m2	-

Table 33 - Early 20th Century Whole-house retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	70.3	kWh/(m2 a)	59.2%
Peak heating load	1.8	kW	62.5%
Emissions rate	601.3	KgCo2, annum	80.2%
EUI (regulated and unregulated)	44.2	kWh/(m2 a)	81.4%
Estimated annual running costs – standard tariff	£841.9	(£/year)	33%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	380	kg.CO2/m2	-

Mid-20th Century typology

Key features

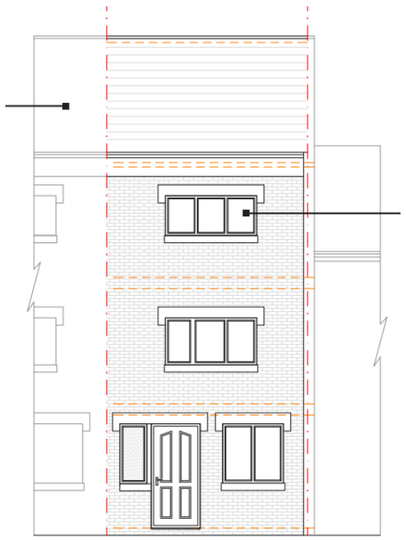


Figure 10 - Mid-20th Century typology facade

The focus of this section has been on low-rise Mid-20th Century dwellings typically consisting of maisonettes and semi-detached type homes, and small flatted developments. Quality of insulation varies significantly with the introduction of building regulations minimum compliance resulting in an important shift within the industry and building standards. This analysis is indicative of a type of mid-20th century dwelling commonly found in Islington, but is not broadly applicable to all mid-century homes.

- **Roof –** Modern roofs are designed with ventilation in mind to reduce the risk of condensation build up and mould, usually done through the installation of air vents located in the eaves. Where ventilation is provided in this way, it should be fully acknowledged when undertaking any retrofit works, such as laying additional insulation in order to avoid unintended consequences of blocking up ventilation pathways
- **Windows -** uPVC systems have been introduced to the UK in the late 1970's, providing an energy-efficient alternative to the commonly used single glazing timber and aluminium windows that came before them.
- **Internal floor/ceiling -** Suspended timbers were not used as part of the build and limit the retrofit of insulation to rigid board type options. The introduction of Building Regulations introduced standard sizing for floor joist, remaining much the same today. From the 1960s, plasterboard was almost exclusively used in ceiling finishing.
- **External walls –** The performance of early cavity walls does differ from that of modern cavity designs, modern cavities (post Building Regulations) having to meet particular performance criteria. The unfilled cavities in a home due to be retrofitted would need to be surveyed to understand the condition and width of the cavity. This will be strong indicator of whether the cavity can be insulated, and with what type of insulation

Baseline information

Table 34 - Mid-20th Century typology fabric performance pre-retrofit

Envelope element	Performance characteristics (W/m2.K)
External wall	0.80
Roof/top floor ceiling	0.50
Floor slab/basement ceiling	1.50
Thermal bridge coefficient (W/(m.K))	-
Glazing (U-value)	1.80
Glazing (g-value)	0.61

Table 35 - Mid-20th Century typology energy performance pre-retrofit

Metric		Units
Annual heat demand	62.4	kWh/(m2a)
Peak heating load	2.9	kW
Emissions rate	2429.8	KgCo2, annum
EUI (regulated and unregulated)	140	kWh/(m2a)
Estimated annual running costs – standard tariff	£1,194	(£/year)

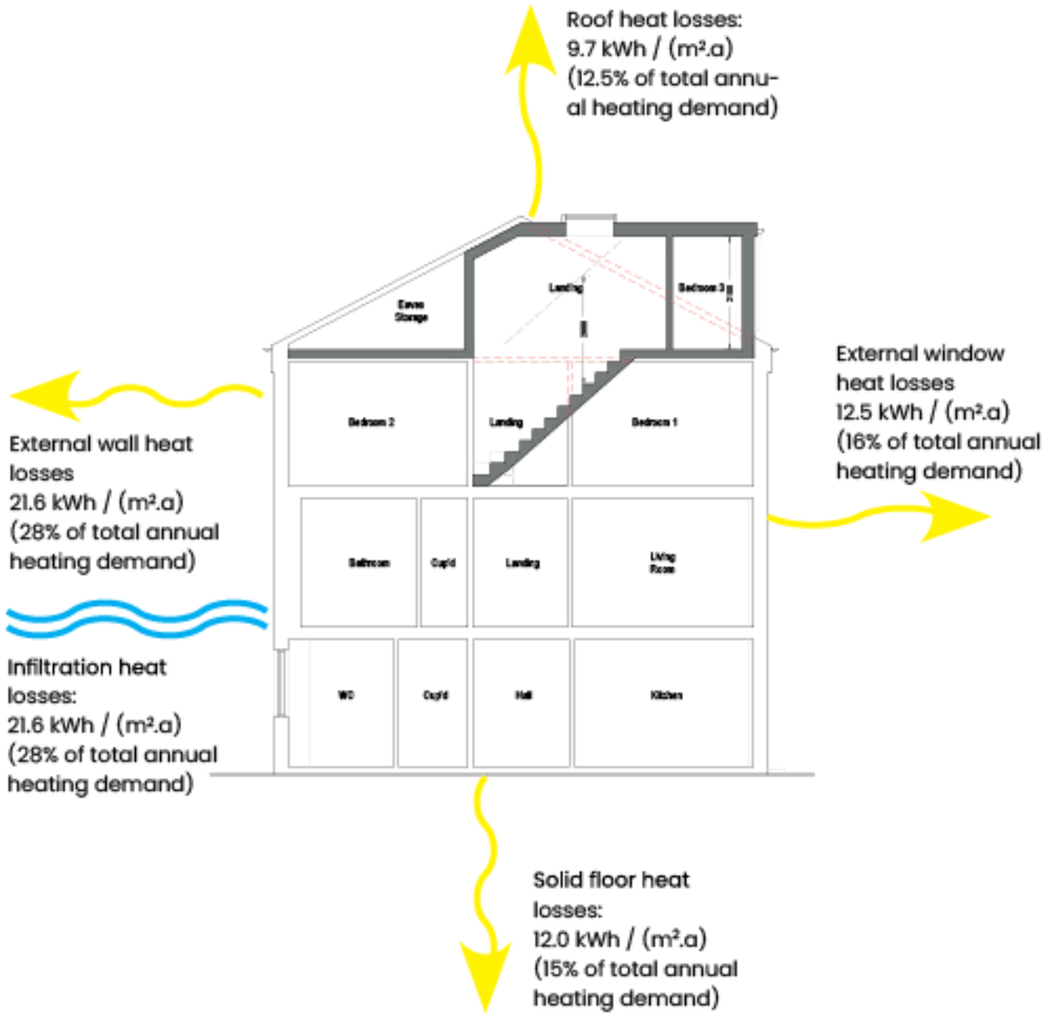


Figure 11 - Mid-20th Century typology heat loss diagram

Evaluation

Evaluation Matrix

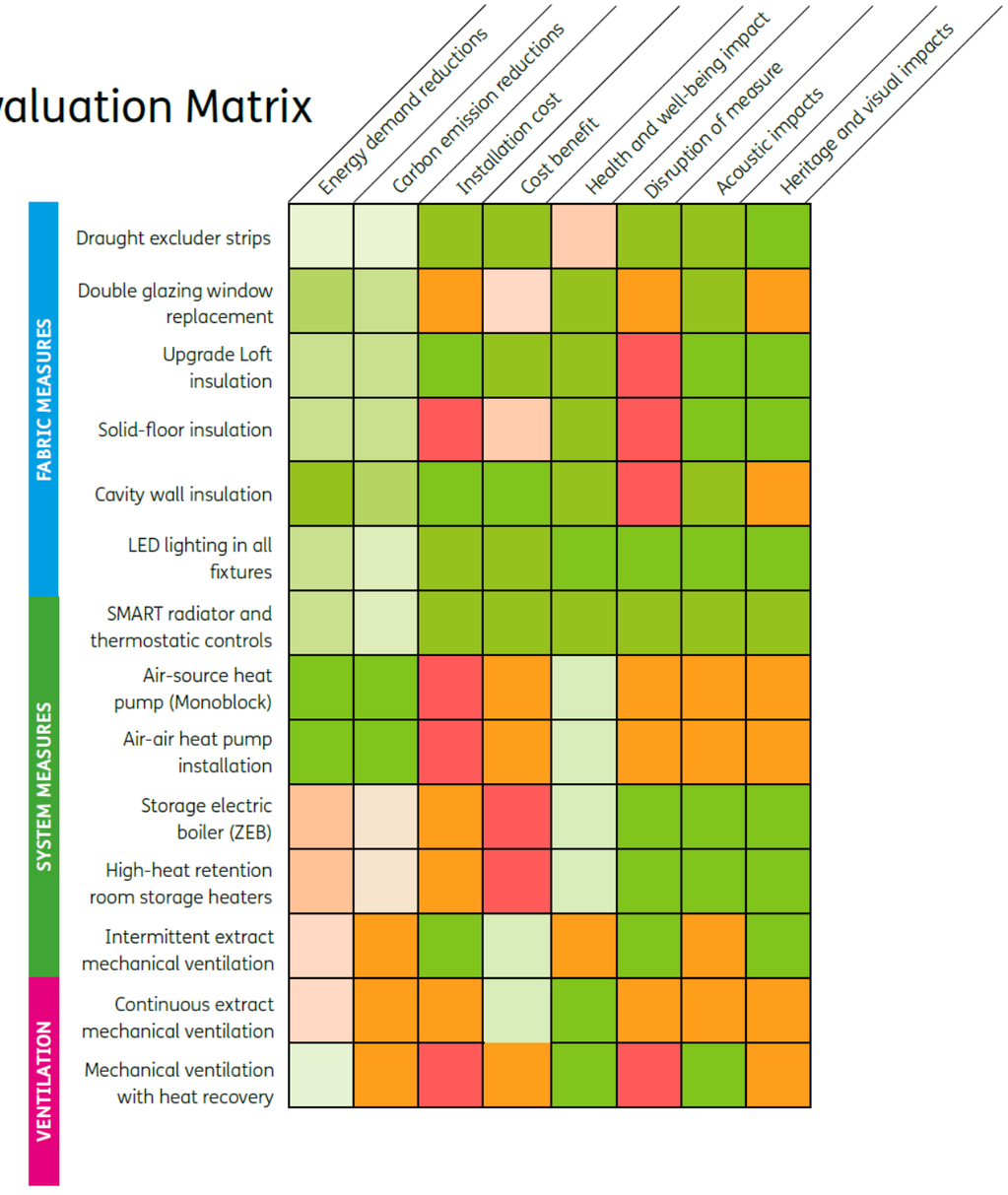


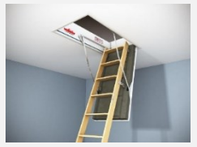
Figure 12 - Mid-20th Century evaluation framework

Table 36 - Mid-20th Century typology scenario evaluation

Evaluation criteria	DIY retrofit	Phased retrofit	Whole-house retrofit
Energy and carbon demand reductions:	For DIY measures, energy demand reductions are particularly tricky to estimate, as they are highly dependent on existing building element condition and installation quality	This scenario prioritises high-value energy demand reductions, and deep carbon reductions through heat-pump installation as early in the process as possible	Carbon emission reductions of around 70% can be achieved through this scenario compared to the baseline building
Installation cost	Lower end estimates represent basic products with no aesthetic sensitivity, higher end costs reflect more premium products fitting into current building elements sensitively	Same as for DIY measures.	Same as for DIY measures.
Heritage	DIY measures tend to be less intrusive and therefore are impacted less by heritage constraints, however they can still alter the condition and overall function if they are incorrectly installed	Heritage constraints are a less significant element of these properties. However, most of the insulation measures proposed are within fabric, and shouldn't have a negative impact on the character of the homes.	As for the phased approach, the insulation measures targeted - loft insulation and cavity wall insultation are within fabric and won't impact on building heritage.
Health and wellbeing impacts	Installation of draught proofing around windows and doors provides a low-cost and immediate impact for the occupant	Wellbeing benefits are attached to Phases 1 and 2 alongside the focus on pragmatic carbon emission reduction. Aereco and improved bathroom / kitchen extracts will significantly improve ventilation through the property, and should improve wellbeing of residents	Fabric upgrade features will deliver health improvements through increased air tightness and generally improved thermal performance. Significant improvements will be seen through the introduction of the MVHR system - delivering fresh air during winter.
Risks	Any alterations to the home should be considered in the context of its existing operations. Potential unintended consequences include increased air tightness, and the requirements associated with ventilation necessary to reduce the risk of damp and mould	The importance of considering ventilation provision through these measures cannot be overstated. This has been prioritised in Phase 1 due to these risks	Any alterations to the home should be considered in the context of its existing operations and condition. Specification of an MVHR active ventilation system should significantly mitigate the risks from a moisture flow perspective.
Sequencing	DIY measures can be installed in any sequence.	Depending on building lifecycle - some phase 3 measures may be installed in Phase 1. E.g. if there is an immediate need for window replacement. The logic of this scenario is to ensure heat-pump installation is prioritised as early as possible in the retrofit journey.	Simultaneous installation of all measures is recommended for maximum cost savings and to ensure clean interfaces

Mid 20th Century typology - DIY retrofit scenario

Table 37 - Mid-20th Century typology DIY retrofit measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
LED lighting		6% electricity	~4%	£150-£1000
Insulated loft hatch	. 	2% gas	~2%	£300- £500
Draught proofing windows and doors		1% gas	~2%	£250- £600
Heating system controls and monitoring		3% gas	~3%	£400-£1000
Total reductions and overall cost		**3% gas ; 6% electricity**	**~5%**	**~1,100-£3,100**

Mid-20th Century typology – Phased retrofit scenario

Table 38 - Mid-20th Century Phase 1 - High value energy efficiency measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
DIY measures		3% gas 6% electricity	~5%	£1,100-£3,100
Top-up loft insulation		7% gas	~5%	£1,000-£3,000
Cavity wall insultation		20% gas	~14%	£3,000-£5,000
Total reductions and overall cost		**28% gas; 6% electricity**	**~15%**	**~£5,100-£11,100**

Table 39 - Mid-20th Century Phase 2 - Electrification and decarbonisation measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
Installation of an ASHP with cylinder DHWS specification of a new cylinder Radiator replacement, resized for HP installation		100% gas 132% electricity	~75%	£3,000 - £6,000[7]

Roof-mounted PV (4kW array)		7% electricity	~5%	£8,000-£10,000
Total reductions and overall cost		**100% gas ; 58% electricity**	**~70%**	**~£11,000-£16,000**

Table 40 - Phase 3 Mid-20th Century Phase 3 - Further measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
Double glazed windows		5% electricity	~5%	£13,000-£20,000
Door replacements		3% electricity	~3%	£1,000-£2,000
Mechanical Ventilation and Heat Recovery (MVHR) installation		5%	~5%	£3,000-£6,000
Total reductions and overall cost		**12% electricity**	**~12%**	**~£17,000-£28,000**

Mid 20th Century typology - Whole-house retrofit scenario

Table 41 - Mid-20th Century Whole-house retrofit measures

Measure	Description	Energy demand reductions	Carbon emission reductions	Installation cost
LED lighting		6% electricity	~4%	£150-£1000
Upgraded insulated loft hatch		9% gas	~5%	£1,300-£3,500
Triple glazed windows Door replacements		12% gas	~7%	£16,000-£24,000
Cavity wall insulation		20% gas	~14%	£3,000-£5,000
MVHR installation		5% gas	~5%	£3,000-£5,000
New air-to-water ASHP DHWS - new cylinder with future solar integration		100% gas 57% electricity	~65%	£3,000-£5,000[8]
Roof-mounted PV (8kW array)		7% electricity	~5%	£14,000-£19,000

Total reductions and overall cost		**47% electricity ; 100% gas**	**~70%**	**~£40,000-£61,000**

Retrofit scenarios performance statistics

Table 42 - Mid-20th Century DIY retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	61.2	kWh/(m2a)	1.9%
Peak heating load	2.85	kW	1.7%
Emissions rate	2,422	KgCo2, annum	0.3%
EUI (regulated and unregulated)	139	kWh/(m2a)	0.7%
Estimated annual running costs – standard tariff	£1,158	(£/year)	2.96%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	11	kg.CO2/m2	-

Table 43 - Mid 20th Century Phased retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	45	kWh/(m2a)	28%
Peak heating load	1.8	kW	38%
Emissions rate	806.3	KgCo2, annum	66.8%
EUI (regulated and unregulated)	42	kWh/(m2a)	70%
Estimated annual running costs – standard tariff	£1,054	(£/year)	11.7%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	330	kg.CO2/m2	-

Table 44 - Mid 20th Century Whole-house retrofit performance

Metric		Units	(%) Reduction to baseline
Annual heat demand	40	kWh/(m2a)	35.9%
Peak heating load	1.7	kW	41.4%
Emissions rate	748.3	KgCo2, annum	69.2%
EUI (regulated and unregulated)	39	kWh/(m2a)	72.2%
Estimated annual running costs – standard tariff	£994	(£/year)	21.3%
Embodied carbon total of measures (Whole life A:C Modules inclusive)	350	kg.CO2/m2	-

Appendix A – Detailed retrofit measures

Georgian typology retrofit measures

Table 45- Georgian typology fabric measures

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Draught excluder strips - window and doors	Draught excluders are flexible strips, typically rubber or rigid foam, fitted to the window frame rebate to reduce air leakage. Allowance accounts for all windows and doors, including Stormguard brush guard.	DIY - make sure to follow manufacturers guidance on strip position, and ensure window frame is clean before application.	Residents need to ensure ventilation pathways, such as air-bricks/trickle vents, are maintained. Draught-proofing is usually the first options to consider for improving thermal performance of windows in older buildings.	In older buildings, a significant proportion of heat loss can come from draughts. These low-cost & DIY measures can save up to 30% on the space heating energy use.	Air-tightness and insulation improvement works can increase condensation and mould risk if adequate ventilation provision is not made. Proper ventilation and airflow in the loft space is essential to ensuring no unintended consequences of the increased air tightness.	As there is no impact on overall character of the property, these alterations do not carry any heritage buildings constraints. Windows are often a major source of air infiltration, draught-proofing is one of the best ways to manage this, improving comfort and reducing energy use, with little or no change to a buildings appearance.
Insulating loft hatch/ door and surround	Insulation strips and draught excluders providing seal around the loft hatch, reducing air leakage pathway.	DIY - application for homeowners.	As above	As above	As above	As above

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Window replacement	Install double glazed sash windows to the rear, including insulated window reveals, replacing poor performance single glazing.	Professional installation	Old single glazed windows and surrounds present a significant air leakage pathway in the home. New window installations should be considered a next step in improving the overall air tightness of a home.	Upgrading single glazed units to modern double glazing will result in significant reductions in heat loss and subsequent reductions in energy bills to the homeowner.	Design plays a key role in heritage window replacements, to replicate original features, proportions and architectural style. A potential solution for heritage applications is vacuum glazing, utilising a vacuum-sealed cavity between two glass panes, to reduce heat transfer and improve overall thermal performance. As a result of the narrow cavity between the panes, as little as 0.2mm, they have the appearance of single-glazed windows, whilst delivering exceptional energy performance.	Full window replacement has the potential to significantly alter the appearance of the home. Therefore, limitations exist as to the products that can be specified. Replacement windows should ensure the tradition- al aesthetic of the home is retained whilst achieving the desired performance standards of a new window construction.
Secondary glazing to front facade	Where there are heritage concerns to the road-facing facade, secondary glazing to be considered to provide the desired improvements to thermal performance.	Professional installation	-	Where heritage concerns limit the installation of DGU, secondary glazing will provide the added thermal performance of a DGU installation without the disruption resulting from a full window replacement.	Where complex windows shapes are considered, installation of secondary glazing can be challenging and will likely require a professional installation to ensure correct fitting. Alteration of the thermal performance in older buildings has the risk of creating interstitial condensation, giving rise to mould and potentially creating health issues for occupants.	In listed homes, total replacement of windows would generally require Listed Building Consent, secondary glazing offers an alternative solution that may not require the same permissions associated with full replacement.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Insulation to flat lead roof / new lead roof	Insulation options: Insulating roof from below. Insulate from above with a new roof installation, removing existing roof and stripping back to rafters.	Professional installation	When insulating the loft space consider ventilation of the cavity to remove the risk of condensation build up.	A considerable proportion (35%) of heat is lost through the roof of an uninsulated home. Ensure sufficient loft/ roof insulation coverage.	Any new insulation installation should consider the risk it poses in terms of trapping heat in the loft space, potentially creating damp and condensation problems that will need managing later on. Flat roofs are preferably insulated from above, this process would involve the use of a layered rigid insulation board in- stalled directly on top of the roofs existing weatherproof layer.	As there is no impact on overall character of the property, these alterations do not carry any heritage buildings constraints.
Solid floor insulation	Solid floor insulation - limecrete slab. Improved ground floor thermal performance through the introduction of thin Aerogel insulation.	Professional installation	-	-	Whilst insulating solid floors will improve thermal performance characteristics of the floor, it can risk exacerbate existing moisture-related problems and cause issues with adjacent construction by diverting moisture towards outer walls. Introducing impermeable damp proof membranes and materials into the floor structure which are highly resistant to moisture are often solutions compatible with traditional construction practices.	Solid ground floors can be significant to the char- acter of an older building. Even in cases where floor finishes does not appear to be of particular historic significance, any work to listed building will likely require a Listed Building Consent.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Thin internal wall insulation (TIWI)	Improved external wall thermal performance with no impact on facade appearance. TIWI + lime plaster coat to internal wall & lime parge coat to external wall.	Professional installation	Consider a part of the renovation package to limit disruption to occupants.	It is estimated that approximately 45% of heat may be lost through solid wall construction.	Wall insulation products will alter the technical performance and characteristics of the original solid wall, exacerbating existing moisture-related problems or creating new ones. In some cases, the technical risk of adding insulation to solid walls is great. Care must be taken with the design and installation of internal insulation to avoid cold bridging, particularly at reveals of windows and doors and wall/floor junctions. It is often necessary to relocate servicing (radiators and associated pipe runs) as well as making adjustment to skirting boards and door architraves.	This type of measure, whether applied internally (IWI or TIWI) or externally (EWI), will alter the appearance of the building. In general, internal wall insulation does not require planning permission, although it is subject to building control. For listed properties it is likely any form of wall insulation will require Listed Building Consent.
Internal wall insulation (IWI)	IWI + lime plaster coat to internal wall & lime parge coat to external wall.	Professional installation	As above	As above	As above	As above

Table 46 - Georgian typology system measures

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
LED lighting	Install low energy bulbs throughout the dwelling. Costs account for modifications to enable dimming to the lighting system.	DIY	N/A	With lighting accounting for approximately 15% of a house- hold's energy bill, switching from a traditional halogen to LED bulb can save around 75% of energy.	N/A	As there is no impact on overall character of the proper- ty, these alterations do not carry any heritage buildings constraints.
Thermostatic radiator valves (TRVs) & boiler weather compensation	TRV installation allows individual room to room radiator temperature control for more efficient temperature modulation, reducing unnecessary heating of vacant spaces. Weather compensation ensures boilers only fire when needed, using only enough gas to maintain the desired temperatures.	Professional gas engineer installation	N/A	Installation of TRVs allows closer control of temperature on a room by room basis, enabling the home owner the ability to eliminate unnecessary heating of vacant rooms. Installation of boiler weather compensation has been shown to realise energy savings of 10 - 40%.	N/A	As there is no impact on overall character of the proper- ty, these alterations do not carry any heritage buildings constraints.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Extract ventilation system (Intermit- tent)	Ensure effective ventilation - including intelligent mechanical extract (iMEV) in kitchens, bathrooms and other wet rooms throughout the home to reduce the risk of damp and condensation.	Professional (Electrician)	N/A	Introduction of a demand con- trolled system/intelligent system ensures, extract is only engaged when required, typically via a humidity sensor.	When installing any ventilation upgrades, a number of key technical considerations must be made to ensure its effective operations, including ensuring installation meets required building standards to guarantee operational performance. Where possible, rigid ducting should be used over flexible alternatives to avoid unnecessary higher resistances and pressure drops through pipe runs, avoiding increases to the systems overall energy consumption. Due to its shape, rigid ducting is also quieter than the flexible alternative and as a result more suited to home applications.	For listed building, Listed Building Consent will be re- quired where there are alterations to either internal or external walls. Very small external equipment installations may not require planning permission if external appearance is not changed significantly.
Extract ventilation system (Intermit- tent with DCV)	As above specified with demand control to ensure operation only when required. Humidity sensor based extract control from wet rooms. Kitchen extract adjusted for direct to outside extract. Aereco style DCV trickle vents. Providing improved ventilation control, but not as good in terms of raw volume, as continuous.	Professional (Electrician)	N/A	As above	As above	As above

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Extract ventilation system (Continuous)	Continuous extract system for kitchens, bathrooms and other wet rooms. Best volume of the extract systems, but not targeted and greater impact on heat losses.	Professional (Electrician)	N/A	-	As above	As above
Whole house ventilation system - Mechanical ventilation with heat recovery (MVHR)	Designed to ensure a healthy internal environment once sufficient levels of air-tightness have been achieved through fabric measures. Systems are designed to reduce moisture build up and ensure good air quality.	Professional	Best performance is seen in applications where air tightness measures have been adopted to ensure air leakage pathways have been sufficiently reduced.	MVHR can recover approximately 90% of the wasted heat in a room, reducing a homes heating requirements by up to 25%.	Design and installation must be carefully aligned, to ensure operational performance matches that of the intended design. Correct MVHR sizing is key to its effective and efficient operation with insufficient sizing having implications on operational efficiency. Design must include sufficient airflow calculations to ensure the fan is fully optimised to correctly circulate air around the property.	Any works that result in alterations to a façade need to be considered in respect to the buildings listing and location. Whole house MVHR and the associated service penetrations must be carefully considered to minimise any visual impact. For listed building, Listed Building Consent will be required.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Heat pump installation	A number of options to be pursued as part of the retrofit coordination process. Installation of a wet ASHP (potentially without the need of resizing radiator system): Hybrid installation - Smaller system to be specified in parallel to a small gas boiler. Where peak heating demand is reduced sufficiently, system can be installed with existing radiator network. Air-to-air heat pump systems: 1.multi-split system can cover 2-5 rooms off single condenser. 2.Roof-mounted, potentially limiting heritage impacts 3.Summer-time comfort cooling to be explored to support summertime overheating mitigation (increase in energy demand).	Professional	Consideration to be given to fabric improvements in parallel to ensure optimised heat pump operation.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas-fired heating.	Technical considerations associated with any ASHP installation will need to be accounted for, including provision of adequate space around the units to allow sufficient air circulation, avoiding exposure to direct sunlight and other heat sources.	On land within a conservation area, an air source heat pump installed on a wall or roof fronting a highway or located between the building and the adjoining high- way, is currently not permitted development and would require planning permission.
Electric boiler (Zero emissions boiler)	Measure provides opportunity for homeowner to easily switch to an all-electric system using the existing network.	Professional	Installation assumes direct switch for existing gas boiler limiting disruption.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas-fired heating.	No significant technical constraints of such an installation given the like for like replacement with the homes existing gas boiler units.	As there is no impact on overall character of the proper- ty, these alterations do not carry any heritage buildings constraints.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
PV installation	Potential to explore the specification of roof-mounted PV as part of the electrification process, combined with battery storage to build in a level of resilience.	Professional	Considered as an easy-win in home energy generation. To be considered as part of a heat pump installation.	Immediate impact of reducing energy bills for the homeowner.	Consideration will need to be given to the physical impact of an installation on the building and whether it can be easily removed at end of life. The expected lifespan of a PV array and its associated equipment is significantly shorted than the roofing. It is important to minimise any roof damage by carefully installing, maintaining, and removing at end of its useful life.	When considering the installation of solar panels, heritage constraints may require planning permission and permitted development rights. Consent is required for installation of any type of PV on a listed building. Planning may be required for buildings in conservation areas. Some heritage assets will not be suitable for PV installation, for instance, homes where the only practical solution is on prominent roof-slopes.

Victorian typology retrofit measures

Table 47 - Victorian typology fabric measures

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Draught excluder strips - windows and doors.	Draught excluders are flexible strips, typically rubber or a rigid foam, which are fitted in the window frame rebate to reduce air leakage. Includes allowance for all windows and doors, including Stormguard brush guard.	DIY - ensure manufacturers guidance on strip position is followed, and ensure window frame is clean before application.	Any improvements to overall air-tightness should consider the implications to mould and condensation risk. Residents need to ensure ventilation pathways, such as air-bricks/trickle vents, are maintained. Where air tightness of loft is increased consideration must be given to ventilation in order to reduce condensation risk.	In older buildings, a significant proportion of heat loss can come from draughts. These low-cost & DIY measures can save up to 30% on the space heating energy use.	Air-tightness and insulation improvement works can increase condensation and mould risk if adequate ventilation provision is not made. Proper ventilation and airflow in the loft space is essential to ensuring no unintended consequences of the increased air tightness.	As there is no impact on overall character of the property, these alterations do not carry any heritage buildings constraints. Windows are often a major source of air in- filtration, draught-proofing is one of the best ways to manage this, improving comfort and reducing energy use, with little or no change to a buildings appearance.
Insulating loft hatch/door and surround	DIY application for homeowners. Insulation strips/draught excluders to provide seal around loft hatch, reducing leakage pathway.	DIY - ensure manufacturers guidance on application is followed.	As above	As above	As above	As above

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Window replacement	Installation of double glazed units (DGU) including insulated window reveals to replace poorly performing single glazing units.	Professional installation	Old single glazed windows and surrounds present a significant air leakage pathway in the home. New window installations should be considered a next step in improving the overall air tightness of a home.	Upgrading single glazed units to modern double glazing will result in significant reductions in heat loss and subsequent reductions in energy bills to the home- owner.	Design plays a key role in heritage window replacements, to replicate original features, proportions and architectural style. A potential solution for heritage applications is vacuum glazing, utilising a vacuum-sealed cavity between two glass panes, to reduce heat trans- fer and improve overall thermal performance. As a result of the narrow cavity between the panes, as little as 0.2mm, they have the appearance of single-glazed windows, whilst delivering exceptional energy performance.	Full window replacement has the potential to significantly alter the appearance of the home. Therefore, limitations exist as to the products that can be specified. Replacement windows should ensure the traditional aesthetic of the home is retained whilst achieving the desired performance standards of a new window construction.
Secondary glazing to front facade	Where there are heritage concerns to the road-facing facade, secondary glazing to be considered to provide the desired improvements to thermal performance.	Professional installation	As above	Where heritage concerns limit the installation of DGU, secondary glazing will provide the added thermal performance of a DGU installation.	As above	As above
Loft insulation	Most homes typically have loft insulation already installed, top-up loft insulation is a quick win for the homeowner.	Professional installation	To be carried out in parallel to loft hatch/surround draught measures.	A considerable proportion (35%) of heat is lost through the roof of an uninsulated home. Ensure sufficient loft insulation coverage, above and be-yond Building Regulations specifications.	When insulating a loft space, ensure sufficient ventilation is provided to eliminate condensation and mould risk. Ideally loft ventilation issues will be addressed in parallel.	Typically no heritage constraints associated with installation of loft insulation.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Suspended ground floor insulation (Q-bot)	Q-bot use to be considered to insulate the ground floor cavity where a home has a suspended ground floor. The mobile Q-bot is used to spray insulation under suspended flooring with minimal disruption, immediately reducing heat lost through the floor and draughts.	Professional installation	Where existing ground floor presents air leakage pathways insulation to be considered alongside other DIY air-tightness measures.	Insulation of leaky, suspended ground floors using the Q-bot insulation can reduce heat losses by up to 77% and decrease cold draughts by 30% across the whole home.	Introduction of Q-bot insulation methodology proposed in this case removes a number of challenges associated with the traditional methods of insulating suspended flooring such as breaks in insulation around joists which can encourage local condensation.	Typically no heritage constraints associated with installation of ground floors within the suspended cavity.
Internal wall insulation (IWI)	IWI installation to road-facing facade (IWI + lime plaster + lime parge) and EWI to the rear wall.	Professional installation	Consider a part of the ren- ovation package to limit disruption to occupants.	It is estimated that approximately 45% of heat may be lost through solid wall construction.	Wall insulation products will alter the technical performance and characteristics of the original solid wall, exacerbating existing moisture-related problems or creating new ones. In some cases, the technical risk of adding insulation to solid walls is great. Care must be taken with the design and installation of internal insulation to avoid cold bridging, particularly at reveals of windows and doors and wall/floor junctions. It is often necessary to relocate servicing (radiators and associated pipe runs) as well as making adjustment to skirting boards and door architraves.	This type of measure, whether applied internally (IWI or TIWI) or externally (EWI), will alter the appearance of the building. In general, internal wall insulation does not require planning permission, although it is subject to building control. For listed proper- ties it is likely any form of wall insulation will require Listed Building Consent.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Thin internal wall insulation (TIWI)	TIWI installation to road-facing facade (TIWI+ lime plaster + lime parge wall (Proctors Aerogel wall liner)) and optional EWI to rear wall. To be installed without removing wall coving. Assume skirting boards to require replacement.	Professional installation	As above	As above	As above	As above
Boxing to semi-rigid ductwork	Improved air tightness around ductwork to reduce overall air leakage of the property.	Professional	When carrying out redecoration works to areas with the home with service penetrations such as kitchen and bathrooms, consider air leakage path-ways.	Whilst appearing like relatively minor details, poorly finished service penetrations for ventilation and boiler flues can create constant air leakage path-ways in a properties façade owing to consistent heat losses and wasted energy.	Particular care should be taken when managing service penetrations through the building façade as these areas can become traps for condensation build-up, ultimately leading to compromised finishes and leading to more significant structural issues at later dates.	Typically, extract ventilation is already present at the property and such interventions do not alter the homes appearance. No heritage constraints are associated with such work.

Table 48 - Victorian typology system measures

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
LED lighting	Low energy LED light bulbs throughout the dwelling. LED lighting is now widespread, affordable, effective and reliable. Costs account for modifications to enable dimming to the lighting system. `	DIY	Standalone installation.	With lighting accounting for ap- proximately 15% of a household's energy bill, switching from a traditional halogen to LED bulb can save around 75% of energy.	N/A	As there is no impact on overall character of the property, these alterations do not carry any heritage buildings constraints.
Thermo static radiator valves (TRVs) & boiler weather compen sation	TRV installation allows individual room to room radiator temperature control for more efficient temperature modulation. Weather compensation ensures boilers only fire when needed, using only enough gas to maintain the desired temperatures.	Profession al gas engineer installation	Standalone installation.	Installation of TRVs allows closer control of temperature on a room by room basis, enabling the home owner the ability to eliminate un- necessary heating of vacant rooms. Installation of boiler weather compensation has been shown to realise energy savings of 10 - 40%.	N/A	As there is no impact on overall character of the property, these alterations do not carry any heritage buildings constraints.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Extract ventilation system (Intermittent)	Ensure effective ventilation - including intelligent mechanical ex- tract (iMEV) in kitchens, bathrooms and other wet rooms through- out the home to reduce the risk of damp and condensation.	Professional (Electrician)	Carrying out redecoration and refit of bathroom and kitchen spaces present a good opportunity to upgrade existing extract systems to ensure moisture and condensation build- up is sufficiently managed.	Introduction of a demand con- trolled system/intelligent system ensures, extract is only engaged when required, typically via a humidity sensor.	When installing any ventilation upgrades, a number of key technical considerations must be made to ensure its effective operations, including ensuring installation meets required building standards to guarantee operational performance. Where possible, rigid ducting should be used over flexible alternatives to avoid unnecessary higher resistances and pressure drops through pipe runs, avoiding increases to the systems overall energy consumption. Due to its shape, rigid ducting is also quieter than the flexible alternative and as a result more suited to home applications.	For listed building, Listed Building Consent will be required where there are alterations to either internal or external walls. Very small external equipment installations may not require planning permission if external appearance is not changed significantly.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Extract ventilation system (Intermittent with Demand Controlled Ventilation)	As above specified with demand control to ensure operation only when required. Humidity sensor based extract control from wet rooms. Kitchen extract adjusted for direct to outside extract. Aereco style DCV trickle vents. Providing improved ventilation control, but not as good in terms of raw volume, as continuous.	Professional (Electrician)	As above	As above	As above	As above
Extract ventilation system (Continuous)	Continuous extract system for kitchens, bathrooms and other wet rooms (with no controls). This system provides the largest overall volume of air of the extract systems, however, not via a targeted approach.	Professional (Electrician)	As above	As above	As above	As above

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Whole house ventilation system - Mechanical ventilation with heat recovery (MVHR)	Designed to ensure a healthy internal environment once sufficient levels of air-tightness have been achieved through fabric measures. Systems are designed to reduce moisture build up and ensure good air quality.	Professional	Best performance is seen in applications where air tightness measures have been adopted to ensure air leakage pathways have been sufficiently reduced.	MVHR can recover approximately 90% of the wasted heat in a room, reducing a homes heating requirements by up to 25%.	Design and installation must be carefully aligned, to ensure operational performance matches that of the intended design. Correct MVHR sizing is key to its effective and efficient operation with insufficient sizing having implications on operational efficiency. Design must include sufficient airflow calculations to ensure the fan is fully optimised to correctly circulate air around the property.	Any works that result in alterations to a façade need to be considered in respect to the buildings listing and location. Whole house MVHR and the associated service penetrations must be carefully considered to minimise any visual impact. Planning permission may be required in a conservation area.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Heat pump installation	A number of options to be pursued as part of the retrofit coordination process. Installation of a wet ASHP (potentially without the need of resizing radiator system): Hybrid installation - Smaller system to be specified in parallel to a small gas boiler. Where peak heating demand is reduced sufficiently, system can be installation with existing radiator network. Air-to-air heat pump systems: multi-split system can cover 2-5 rooms off single condenser. Roof-mounted, potentially limiting heritage impacts Summer-time comfort cooling to be explored to support summertime overheating mitigation (increase in energy demand).	Professional	Consideration to be given to fabric improvements in parallel to ensure optimised heat pump operation.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas- fired heating.	Technical considerations associated with any ASHP installation will need to be accounted for, including provision of adequate space around the units to allow sufficient air circulation, avoiding exposure to direct sunlight and other heat sources.	On land within a conservation area, an air source heat pump installed on a wall or roof fronting a highway or located between the building and the adjoining highway, is currently not permitted development and would require planning permission.
Electric boiler (Zero emissions boiler)	Measure provides opportunity for homeowner to easily switch to an all-electric system using the existing network.	Professional	Installation assumes direct switch for existing gas boiler limiting disruption.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas- fired heating.	No significant technical constraints of such an installation given the like for like replacement with the homes existing gas boiler units.	As there is no impact on overall character of the property, these alterations do not carry any heritage buildings constraints.

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
PV installation	Potential to explore the specification of roof-mounted PV as part of the electrification process, combined with battery storage to build in a level of resilience.	Professional	Considered as an easy- win in home energy generation. To be considered alongside heat pump installation.	Immediate impact of reducing energy bills for the homeowner.	Consideration will need to be given to the physical impact of an installation on the building and whether it can be easily removed at end of life. The expected lifespan of a PV array and its associated equipment is significantly shorted than the roofing. It is important to minimise any roof damage by carefully installing, maintaining, and removing at end of its useful life.	When considering the installation of solar panels, heritage constraints may require planning permission and permitted development rights. Consent is required for installation of any type PV on a listed building. Planning may also be required for buildings In conservation areas

Early 20th century retrofit measures

Table 49 - Early 20th century fabric measures

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Draught strips on windows and doors	Draught excluders are flexible strips, typically rubber or a rigid foam, which are fitted in the window frame rebate to reduce air leakage. Includes allowance for all windows and doors, including Stormguard brush guard.	DIY - make sure to follow manufacturers guidance on strip position, and ensure window frame is clean before application.	Without correctly addressing ventilation, air-tightness measures can have negative impacts on the condition of the home. Without ensuring adequate ventilation is provided, the homes im- proved air tightness, combined with insulation upgrades will increase the risk of moisture and condensation and ultimately mould build-up. Residents need to ensure ventilation pathways, such as air-bricks and trickle vents are in place and maintained to eliminate these problems.	In older buildings, a significant proportion of heat loss can come from draughts. These low-cost & DIY measures can save up to 30% on the space heating energy use.	Air-tightness and insulation improvement works can increase condensation and mould risk if adequate ventilation provision is not made. Irrespective of the degree to which air tightness measures are applied, proper ventilation and airflow should be considered a pre-requisite to ensure unintended consequences in the form of damp and mould build up does not occur.	N/A
Further air tightness measures (Option 1)	All service penetrations through the external are sealed and redundant ventilation penetrations removed. One blower door test to be carried out to identify leakage pathways. All leakage pathway revealed from testing to be sealed.	Professional	As above	As above	As above	As above

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Further air tightness measures (Option 2)	In addition to measures in outlined in Option 1, further air-tightness measures include the following: Air tightness tape (e.g. Pavatext Pavawin to all new windows and doors) Patch repairs to cracks in ceiling and existing walls with liquid applied air tightness membrane. Parge coat to walls Additional blower door test after implementation of measures to identify and remedy any outstanding issues.	Professional	As above	As above	As above	As above
Low-e film on inside of double glazing	DIY window film to improve existing windows thermal performance.	DIY	Old single glazed windows and surrounds, as well as older poorly performing double glazed units present a significant air leakage pathway in the home. New window installations should be considered a next step in im- proving the overall air tightness of a home.	Upgrading single glazed units to modern double glazing will result in significant reductions in heat loss and subsequent reductions in energy bills to the homeowner.	When installing any new window and door units, it is important to consider the risks associated with thermal bridging. If either window or doors are located within non-insulative construction layers, thermal bridges will be created where heat can easily escape. Careful attention should be paid to the detailing of these elements to eliminate this issue, this can achieved through caulking around window frames.	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Window replacement (Low-e double glazing)	Install low e double glazed windows to greater improve thermal performance of the facade.	Professional				
Triple glazed windows	Further improved thermal performance through triple glazing specification.	Professional				
Door replacement	Newly replaced doors and associated air tightness measures to reduce leakage pathway.	Professional	To be considered alongside other façade measures to reduced air leakage pathways.	–		
Ground floor insulation with thin aerogel insulation	Improved ground floor thermal performance	Professional	Adding ground floor insulation will reduce heat losses and cold draughts through the existing floor, whilst reducing heat demand to maintain a comfortable environment.	Homes could be losing approximately 10-20% of their heat through uninsulated suspended timber floors.	Although more expensive than other insulating materials, aerogel has several advantages such as achieving a low thermal conductance, meaning high levels of insulation can be achieved for relatively little depth.	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Internal wall insulation (IWI)	Improved external wall thermal performance with no impact on facade appearance.	Professional	Consider a part of the renovation package to limit disruption to occupants.	External walls present one of the biggest opportunity areas for reducing heat loss in the home.	Care must be taken with the design and installation of internal insulation to avoid cold bridging, particularly at reveals of windows and doors and wall/floor junctions. It is often necessary to relocate servicing (radiators and associated pipe runs) as well as making adjustment to skirting boards to ensure there are no breaks in insulation.	Whilst homes are typically not listed from this period, consideration should be made to other occupants within the property. It may be necessary to obtain planning consent for any works that alter the appearance of a dwelling.
Thin internal wall insulation (TIWI)	TIWI + lime plaster coat to internal wall & lime parge coat to external wall.	Professional	As above	As above	As above	As above

Table 50 - Early 20th century system measures

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
LED lighting	Install low energy bulbs throughout the dwelling. Costs account for modifications to enable dimming to the lighting system.	DIY	Standalone installation.	With lighting accounting for approximately 15% of a household's energy bill, switching from a traditional halogen to LED bulb can save	N/A	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
				around 75% of energy		
Extract ventilation system (Bathroom)	Ensure effective ventilation - including intelligent mechanical extract (iMEV) in kitchens, bathrooms and other wet rooms throughout the home to reduce the risk of damp and condensation.	Professional (Electrician)	Standalone installation.	Introduction of a demand controlled system/intelligent system ensures, extract is only engaged when required, typically via a humidity sensor and therefore reduces unnecessary energy consumption.	When installing any ventilation upgrades, a number of key technical considerations must be made to ensure effective operations, including ensuring installation meets required building standards to guarantee operational performance.	N/A
Extract ventilation (kitchen)	As above	Professional (Electrician)	Carrying out redecoration and refit of bathroom and kitchen spaces present a good opportunity to upgrade existing extract systems to ensure moisture and condensation build-up is sufficiently managed.			
Extract ventilation system (Bathroom via humidity control)	As above specified with demand control to ensure operation only when required. Humidity sensor based extract control from wet rooms.	Professional (Electrician)				
Local Mechanical ventilation with heat	Designed to ensure a healthy internal environment once sufficient levels of air-tightness have been achieved through fabric	Professional (Electrician)	Best performance is seen in applications where air tightness measures have been adopted to ensure air	MVHR can recover approximately 90% of the wasted heat in a room, reducing a homes	Design and installation must be carefully aligned, to ensure operational performance matches that of the intended design.	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
recovery (MVHR)	measures. Systems are designed to reduce moisture build up and ensure good air quality.		leak- age pathways have been sufficiently reduced.	heating requirements by up to 25%.	Correct MVHR sizing is key to its effective and efficient operation with insufficient sizing having implications on operational efficiency. Design must include sufficient airflow calculations to ensure the fan is fully optimised to correctly circulate air around the property.	
Power upgrades to existing network	Upgrades to existing electrical systems	Professional (Electrician)	Standalone installation.	Updated electrical switchgear and wiring improving operating efficiency.	N/A	N/A
New electric eco boiler/ storage system	Measure provides opportunity for homeowner to easily switch to an all-electric system using the existing network.	Profession al	Installation assumes direct switch for existing gas boiler limiting disruption.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas-fired heating.	No significant technical constraints of such an installation given the like for like replacement with the homes existing gas boiler units.	N/A
Heat pump installation - ASHP with cylinder	A number of options to be pursued as part of the retrofit coordination process. Installation of a wet ASHP where peak heating demand is reduced sufficiently, system can be installed with existing radiator network.	Profession al	Consideration to be given to fabric improvements in parallel to ensure optimised heat pump operation.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas-fired heating.	Technical considerations associated with any ASHP installation will need to be accounted for, including provision of adequate space around the units to allow sufficient air circulation, avoiding exposure to direct sunlight and other heat sources.	N/A
Heat distribution	Radiator replacement for heat installation	Profession al	–	–	N/A	N/A
Controls - Centralised smart controls	Centralised controls of heating systems to enable easy regulation to reduce avoidable over-heating	Profession al	–	–	N/A	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
	when spaces are unoccupied.					

Mid-20th century retrofit measures

Table 51 - Mid-20th century fabric measures

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Draught strips on windows and doors	Draught excluders are flexible strips, typically rubber or a rigid foam, which are fitted in the window frame rebate to reduce air leakage. Includes allowance for all windows and doors, including Stormguard brush guard.	DIY - make sure to follow manufacturers guidance on strip position, and ensure window frame is clean before application.	Without correctly addressing ventilation, air-tightness measures can have negative impacts on the condition of the home. Without ensuring adequate ventilation is provided, the homes improved air tightness, combined with insulation upgrades will increase the risk of moisture and condensation and ultimately mould build-up. Residents need to ensure ventilation pathways, such as air-bricks and trick- le vents are in place and maintained to eliminate these problems.	These low-cost & DIY measures can add up to significant savings on the space heating energy use of a property. Regarding the more intrusive, professionally installed options, new loft hatch installation provide even greater savings.	Air-tightness and insulation improvement works can increase condensation and mould risk if adequate ventilation provision is not made. Irrespective of the degree to which air tight- ness measures are applied, proper ventilation and airflow should be considered a pre-requisite to ensure unintended consequences in the form of damp and mould build up does not occur.	N/A
DIY improvements to loft hatches	Insulation strips/draught excluders providing a seal around loft hatch, reducing leakage pathway.	DIY - application for homeowners.	As above	As above	As above	N/A
New loft hatch	Correctly installed loft hatches can provide improved energy efficiency, preventing heat loss and draughts	Professional installation	As above	As above	As above	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Further air tightness measures (Option 1)	All service penetrations through the external are sealed and redundant ventilation penetrations removed. One blower door test to be carried out to identify leakage pathways. All leakage pathway revealed from testing to be sealed.	Professional installation	As above	As above	As above	N/A
Further air tightness measures (Option 2)	In addition to measures in outlined in Option 1, further airtightness measures include the following: Air tightness tape (e.g. Pavatext Pavawin to all new windows and doors) Patch repairs to cracks in ceiling and existing walls with liquid applied air tightness membrane. Parge coat to walls Additional blower door test after implementation of measures to identify and remedy any outstanding issues.	Professional installation	As above	As above	As above	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Window replacement (Low-e double glazing)	Install low e double glazed windows to greater improve thermal performance of the facade.	Professional installation	New window installations should be considered alongside other façade measures such as external wall insulation.	Upgrading single glazed units to modern double glazing will result in significant reductions in heat loss and subsequent reductions in energy bills to the homeowner.	When installing any new window and door units, it is important to consider the risks associated with thermal bridging. If either window or doors are located within non-insulative construction layers, thermal bridges will be created where heat can easily escape. Careful attention should be paid to the detailing of these elements to eliminate this issue, this can achieved through caulking around window frames. `	N/A
Triple glazed windows and double glazed low E sliding door to rear garden	Further improved thermal performance through triple glazing specification.	Professional installation	As above	As above	As above	N/A
Door replacement	Reduced air leakage pathways.	Professional installation	To be considered alongside other façade measures to reduced air leak- age pathways.	–	As above	N/A
Ground floor insulation with thin aerogel insulation	Improved ground floor thermal performance.	Professional installation	–	Adding ground floor insulation will reduce heat losses and cold draughts through the existing floor, whilst reducing heat demand to maintain a comfortable environment.	Although more expensive than other insulating materials, aerogel has several advantages such as achieving a low thermal conductance, meaning high levels of insulation can be achieved for relatively little depth.	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Wall insulation - CWI to front and rear elevation and end of terrace	Improved external wall thermal performance with no im- pact on facade appearance.	Professional installation	Dependent on the type of construction, a number of external wall insulation specifications are available to address this problem. With all types of wall insulation around the property it is worth considering other works that require external access at height as well as room redecoration to minimise future disruption to the occupant.	Approximately a third of all heat lost in uninsulated properties is through external walls. Insulating external wall will save energy and reduce occupant heating bills.	Care must be taken with the design and installation of cavity wall insulation to avoid uneven coverage which can lead to condensation and damp issues within the cavity. When considering IWI, it is often necessary to relocate servicing (radiators and associated pipe runs) as well as making adjustment to skirting boards to ensure there are no breaks in insulation.	N/A
Wall insulation - internal wall insulation (IWI) to front/ rear elevation and end of terrace	Improved external wall thermal performance with no im- pact on facade appearance.	Professional installation	As above	As above	As above	N/A
Improvements to attic floor	Improved thermal performance of loft, improved air tightness and reduced heat losses.	Professional installation	When insulating a loft space, ensure sufficient ventilation is provided to eliminate condensation and mould risk. Ideally loft ventilation issues will be addressed in parallel.	A considerable proportion (35%) of heat is lost through the roof of an uninsulated home. Ensure sufficient loft floor insulation coverage, above and beyond Building Regulations specifications.	Where ventilation currently exist, ensure any works does not prevent its function, ultimately creating damp and mould issues.	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage constraints
Boxing to semi-rigid ductwork	Improved air tightness around ductwork to reduce overall air leakage of the property.	Professional installation	When carrying out redecoration works to areas with the home with service penetrations such as kitchen and bathrooms, consider air leakage pathways.	Poorly finished service penetrations for ventilation and boiler flues can create constant air leakage pathways in a properties façade owing to consistent heat losses and wasted energy.	Care should be taken when managing service penetrations through the façade as these areas can become traps for condensation build-up, ultimately leading to compromised finishes and leading to more significant structural issues at	N/A

Table 52 - Mid-20th century system measures

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage
LED lighting	Installation of low energy light bulbs throughout the home. Costs account for modifications to enable dimming to the lighting system.	DIY	Standalone installation.	With lighting accounting for approximately 15% of a household's energy bill, switching from a traditional halogen to LED bulb can save around 75% of energy	N/A	N/A
Extract ventilation system (Bathroom)	Ensure effective ventilation - including intelligent mechanical extract (iMEV) in kitchens, bathrooms and other wet rooms throughout the home to reduce the risk of damp and condensation.	Professional (Electrician)	Carrying out redecoration and refit of bath- room and kitchen spaces present a good opportunity to upgrade existing extract systems to ensure moisture and condensation build-up is sufficiently managed.	Introduction of a demand controlled system/intelligent system ensures, extract is only engaged when required, typically via a humidity sensor.	When installing any ventilation upgrades, a number of key technical considerations must be made to ensure effective operations, including ensuring installation meets required building standards to guarantee operational performance.	N/A
Extract ventilation (kitchen)	As above	Professional (Electrician)				
Extract ventilation system (Bathroom via humidity control)	As above specified with demand control to ensure operation only when required. Humidity sensor based extract control from wet rooms.	Professional (Electrician)				

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage
Local Mechanical ventilation with heat recovery (MVHR)	Designed to ensure a healthy internal environment once sufficient levels of air-tight- ness have been achieved through fabric measures. Systems are designed to reduce moisture build up and ensure good air quality.	Professional (Electrician)	Best performance is seen in applications where air tightness measures have been adopted to ensure air leakage pathways have been sufficiently reduced.	MVHR can recover approximately 90% of the wasted heat in a room, reducing a homes heating requirements by up to 25%.	Design and installation must be carefully aligned, to ensure operational performance matches that of the intended design. Correct MVHR sizing is key to its effective and efficient operation with insufficient sizing having implications on operational efficiency. Design must include sufficient airflow calculations to ensure the fan is fully optimised to correctly circulate air around the property.	N/A
Power upgrades to existing network	Upgrades to existing electrical systems	Professional (Electrician)	Standalone installation.	Updated electrical switchgear and wiring improving operating efficiency.	N/A	N/A
New electric eco boiler/ storage system	Measure provides opportunity for homeowner to easily switch to an all-electric system using the existing network.	Professional	Installation assumes direct switch for existing gas boiler limiting disruption.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas-fired heating.	No significant technical constraints of such an installation given the like for like replacement with the homes existing gas boiler units	N/A
Heat generation - New ASHP via Hybrid system	Enables the effective shift to part electric heating supply whilst retaining the existing distribution within the dwelling.	Professional	Consideration to be given to fabric improvements in parallel to heat pump specification to reduce heat demand and fabric heat losses to ensure the most efficient heat pump operation.	As above	Technical considerations associated with any ASHP installation will need to be ac- counted for, including provision of adequate space around the units to allow sufficient air circulation, avoiding exposure to direct sunlight and other heat sources.	

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage
DHWS Services - New Cylinder		Professional	–	–	N/A	N/A
Heat pump installation - ASHP with cylinder	A number of options to be pursued as part of the retrofit coordination process. Installation of a wet ASHP where peak heating demand is reduced sufficiently, system can be installed with existing radiator network.	Professional	Consideration to be given to fabric improvements in parallel to ensure optimised heat pump operation.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas-fired heating.	Constraints similar to those for the hybrid ASHP specification.	N/A
Heat distribution	Radiator replacement for heat installation to ensure the most efficient system operation.	Professional	When wet heating system is specified correct radiator sizing will ensure the most efficient operation. To be consider in parallel to fabric improvements to reduce overall heat demand.	Correctly sized heat emitters will ensure the most efficient heat distribution throughout the home.	N/A	N/A
Controls - Local controls / Central smart	Centralised controls of heating systems to enable easy regulation to reduce avoidable over-heating when spaces are unoccupied.	Professional	Installation assumes direct switch for existing gas boiler limiting disruption.	Electrification has an immediate impact in decarbonising the home, shifting away from traditional gas-fired heating.	N/A	N/A

Measure	Application of measure	Installation	Relation to other measures	Energy benefits	Technical challenges	Heritage
PV installation	Potential to explore the specification of roof-mounted PV as part of the electrification process, combined with battery storage to build in a level of resilience.	Professional	Considered as an easy-win in home energy generation. To be considered alongside heat pump installation.	Immediate impact of reducing energy bills for the homeowner.	N/A	N/A

Appendix B – Whole-house retrofit approach

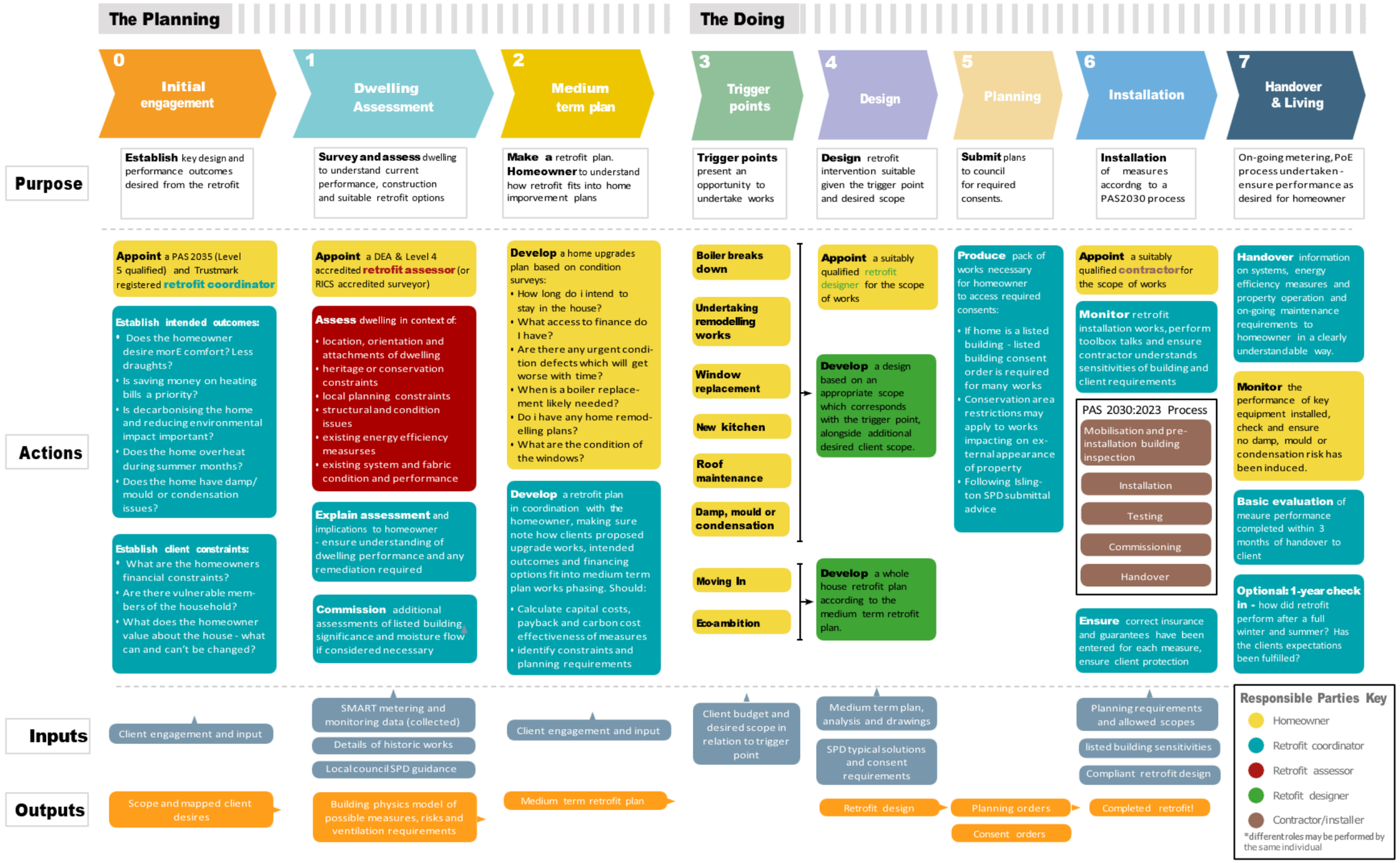


Figure 13 - Whole house retrofit approach