Programme Area: Buildings

Project: Building Supply Chain for Mass Refurbishment of Houses

Title: Whole house solutions report

Abstract:

Please note this report was produced in 2011/2012 and its contents may be out of date. This deliverable is number 3b of 7 in Work Package 3. It builds on the research carried out for the Technical Solutions Matrix (D3.3a). Using the Evaluation Matrices developed previously as a decision guide, this report tackles the challenge of developing generic whole house solutions for a set of representative house types, namely 3 bed semidetached house, mid-rise flat, high rise flat, hard to treat home. A preliminary analysis of the impact of the defined retrofit interventions is included in this deliverable.

Context:

This project looked at designing a supply chain solution to improve the energy efficiency of the vast majority of the 26 million UK homes which will still be in use by 2050.It looked to identify ways in which the refurbishment and retrofitting of existing residential properties can be accelerated by industrialising the processes of design, supply and implementation, while stimulating demand from householders by exploiting additional opportunities that come with extensive building refurbishment.The project developed a top-to-bottom process, using a method of analysing the most cost-effective package of measures suitable for a particular property, through to how these will be installed with the minimum disruption to the householder. This includes identifying the skills required of the people on the ground as well as the optimum material distribution networks to supply them with exactly what is required and when.

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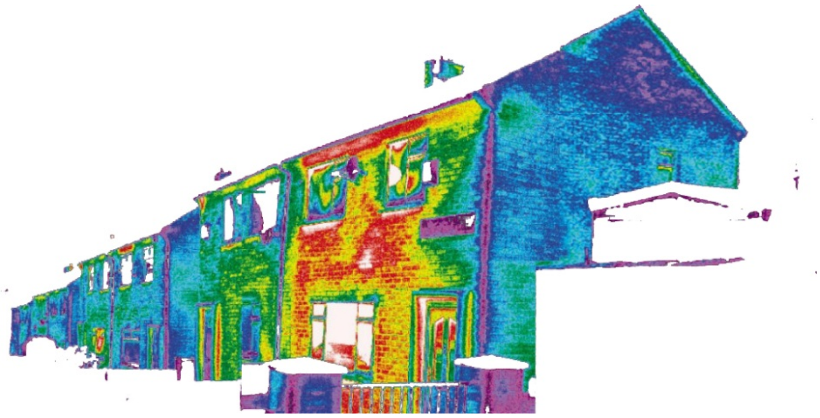

Optimising Thermal Efficiency of Existing Housing

Whole House Solutions Report

Final Report

Submitted by PRP on behalf of the
ENERGY ZONE CONSORTIUM

30 June 2011

Optimising Thermal Efficiency of Existing Housing

Whole House Solutions Report

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Issue	**Final issue**
Action	☐ Accepted ☐ Accepted subject to minor changes ☐ Major re-issue required ____________________ Signature

Contents

Executive Summary

The Whole House Solutions Report (WP3.3b) builds on the research carried out for the Technical Solutions Matrix (WP 3.3a). Using the matrices as a decision guide, this report tackles the challenge of developing generic whole house solutions for a set of representative house types.

Workshop and Report Objectives

- To consider issues related to deliverability, quality, cost, performance, scalability, replicability, adaptability and flexibility, programme
- To present issues for a representative set of house types
- To present a logical progression from the Technical Solutions Matrix work, incorporating technical solutions that have emerged as the best in terms of the combined variables associated with design, construction, supply chain, cost, carbon savings and customer value.
- Take on board the findings and lessons learnt from previous workpackage activities.

These key findings from the Technical Solutions Report have been taken on board during the process of determining the solutions. Due to the range of house types available, we have selected four types that are distinctly different from each other in order to work through the range of unique constraints posed by each type. The four types are as follows:

1. Three bed semi detached house
2. Mid-rise block of flats
3. High-rise tower block
4. Hard to Treat property

Each of these types was analysed in terms of the following framework:

1. Existing condition - what might you find in a property of this type?
2. Issues and Risks - what are the challenges and unknowns?
3. Improvement Options - what can you do to make the property more thermally efficient?
4. Innovation Options - solutions that are not in the mainstream yet but have the potential to solve difficult problems at the critical building junctions. These take on board the findings from a Retrofit Innovations workshop that was held as part of this workpackage.

Costing exercises were also carried out on the most dominant type using current costing methodology. The exercise showed that the cost for a whole house retrofit is quite high and that there is a lot of potential for optimising the process (of the costing itself as well as the retrofit activity) in order to bring down the costs for the future supply chain.

The report also discusses the implications of the smart meter rollout on any national retrofit activity.

Introduction

KEY FINDINGS - EVALUATION MATRICES

The Evaluation Matrices from the WP3.3a Technical Solutions Report showed that the "Top 5" interventions are the ones that have already been widely accepted and have been partially implemented across the housing stock - loft insulation, cavity wall insulation, tank and pipe insulation, high efficiency boiler installation, draughtproofing and repair of doors and windows. Building control systems, smart meters, airtightness, internal wall insulation and external wall insulation complete the "Top 10" easy wins that rate highly on a set of criteria including deliverability, quality, cost, performance, scalability, replicability, adaptability and flexibility, and programme.

In terms of opportunities to add value to the retrofit exercise, the most highly rated non-thermal add-ons were new fitted wardrobes and shelves, which could potentially be used as a "hook" for customers to encourage them to undertake retrofits. This is followed by interior redecoration, new kitchens and bathrooms, rooflights/solar pipes and garden landscaping. The lowest indicative values for the "hooks" were for greywater recycling systems and conservatory/sunrooms.

The lowest indicative values for thermal improvements were received by ground floor insulation, room in roof, rebuilding external walls, MVHR, underfloor heating, and heat pumps.

KEY FINDINGS - SYNERGY MATRICES

Based on our "Top 10" likely interventions then, the following synergies are recommended for each of the fabric-related interventions:

- Loft Insulation - best done in conjunction with re-roofing, room in roof and roof light/ solar pipe installation
- Tank and pipe insulation - best done in conjunction with boiler installation
- New high-efficiency boiler installation - best done in conjunction with tank and pipe insulation, solar hot water system installation
- Draughtproofing - best done in conjunction with replacement doors and windows, repair of doors and windows, airtightness improvements
- Repair/improvement of doors and windows - best done in conjunction with draughtproofing, thermal bridging and condensation solutions, and airtightness improvements
- Airtightness improvements - best done in conjunction with re-roofing, room in roof, replacement doors and windows, draughtproofing, repair of doors and windows, cavity wall insulation, internal wall insulation, thermal bridging and condensation improvements, MVHR installation and new kitchen/bathroom.
- External Wall Insulation - best done in conjunction with replacement doors and windows, insulation for tunnels and passages

- Internal Wall Insulation - best done in conjunction with replacement doors and windows, airtightness improvements, thermal improvement of existing extensions, new kitchen/bathroom, and new fitted wardrobes and shelves.

These key findings have been taken on board during the process of determining the solutions. Due to the range of house types available, we have selected four types that are distinctly different from each other in order to work through the range of unique constraints posed by each type. The four types are as follows:

5. Three bed semi detached house
6. Mid-rise block of flats
7. High-rise tower block
8. Hard to Treat property

Resolving the stock

Three-bed semi-detached houses. In simple terms, semi-detached houses have a front façade, a rear façade, a gable end and a party wall. We have chosen this type to look at more closely because it has most of the elements for houses that are divided vertically. End terrace flats are a very similar type - it differs from a semi-detached in that it is attached to a longer row of houses instead of just one house. Mid-terrace flats have a front façade and a rear façade, but instead of having a gable end and a party wall, they have two party walls on either side. Then finally, you have detached houses which have a front façade, a rear façade, and other walls which could either closely resemble a gable end or a front or rear façade. One consideration that is more of an issue with detached houses than semi-detached houses is the possible presence of extensions to the original building fabric. Bungalows are an ambiguous house type that covers anything that is single-storey but could be detached, semi-detached, end terrace or mid-terrace.

Taken as a group, all of these house types together (excluding everything built before 1919) amount to 65.1% of the English housing stock.

Mid-rise blocks of flats. This house type consists of housing units that are stacked vertically and horizontally, and differ from semi-detached in that for mid-rise blocks you would have stair lobbies, shared external circulation spaces, party walls and party floors. Taken as a group, these amount to 12.1% of the English housing stock.

High-rise tower blocks. This house type again consist of housing units that are stacked vertically and horizontally but in this case are taller and have lift lobbies and parapet walls at the top. These only account for a small percentage of the English housing stock at 1.5% but are nevertheless an interesting study as they pose some refurbishment problems that do not exist for the other two.

Hard-to-treat. This is the most challenging house type to develop generic solutions for, as it cannot be generalized easily. These consist mainly of pre-1919 properties, which vary greatly across the stock in terms of construction type, materials, appearance, and fabric configuration. These are often in poor condition both thermally and structurally and the ones that are not are normally located in conservation areas or are listed. Pre-1919 properties make up 21.2% of the English Housing Stock.

The example illustrated as the starting point for this study is a terrace of 3no. three-storey houses in a Conservation Area, bordering directly onto the back edge of pavement with no front garden. Forms of construction for other house types falling under this heading were also considered.

Due to the wide variation present in the house types, we have decided to take an issues-based and component-based approach to generating the solutions. Often a solution will be the same across two different house types for a particular issue regardless of the type. What we present here is an initial framework for developing solutions, but the solutions are not meant to be cast in stone and we acknowledge that every property will be different and some flexibility will be required in order to adapt these solutions. What we are trying to do is make the decision-making process transparent and replicable.

Each of these types was analysed in terms of the following framework:

1. Existing condition - what might you find in a property of this type?
2. Issues and Risks - what are the challenges and unknowns?
3. Improvement Options - what can you do to make the property more thermally efficient?
4. Innovation Options - solutions that are not in the mainstream yet but have the potential to solve difficult problems at the critical building junctions. These take on board the findings from a Retrofit Innovations workshop that was held as part of this workpackage.

Technical Solutions

Wall Insulation

Solid Walls

In energy terms, external wall insulation is the most effective method of insulating any wall since there is greater potential for thicker insulation than with internal or cavity wall insulation. The maximum feasible level of insulation should be installed. U-values achievable by the addition of external wall insulation of phenolic foam of varying thicknesses with a thermal conductivity of l=0.025 are shown below. Building regulations part L1B 2010 require that a wall with internal or external insulation achieve a U-value of 0.30 W/m^{2}K.

Solid Wall U-values: External Wall Insulation	
External Insulation (mm)	Solid Wall U-values values (W/m2K)
0	2.198
100	0.224
150	0.155
200	0.118

Constraints

In some cases the roof eaves and / or verges may not be deep enough to accommodate large thicknesses of external wall insulation. The preferred solution is to extend the eaves or verges, and where this is not possible external wall insulation thickness can be reduced to a practical level.

Installation of external wall insulation generally requires repositioning of externally mounted or routed property services such as rain water pipes, utility meters, and communication equipment. When the property is adjacent to a property that will not be applying external wall insulation, the additional thickness of the wall of the insulated property will result in a step in the facade line on the centre of the party wall. When a neighbouring property cannot be insulated in the same way, additional insulation will need to be installed in the form of internal wall insulation to 600mm perpendicular to the edge of the insulation at the party wall to mitigate cold bridging.

Where the thickness would necessarily be reduced below 80mm, internal wall insulation should also be considered. Internal wall insulation can be very disruptive to install as it usually involves multiple trades and redecoration. Installation of internal wall insulation can cause problems with interstitial condensation where warm high moisture content air condenses on an internal wall surface.

Cavity walls

In energy terms, external wall insulation, even of cavity walls, is the most effective method of insulating any wall since the thickness of the insulation is not as limited as cavity wall fill or internal wall insulation.

Cavity Wall U-values: External Wall Insulation with Unfilled Cavity	
External Insulation (mm)	Solid Wall U-values values (W/m^{2}K)
0	1.585
100	0.215
150	0.15
200	0.116

However, cavity wall fill insulation represents one of the most cost effective energy efficiency measures; the payback time for cavity wall insulation is likely to be fewer than 4 years.

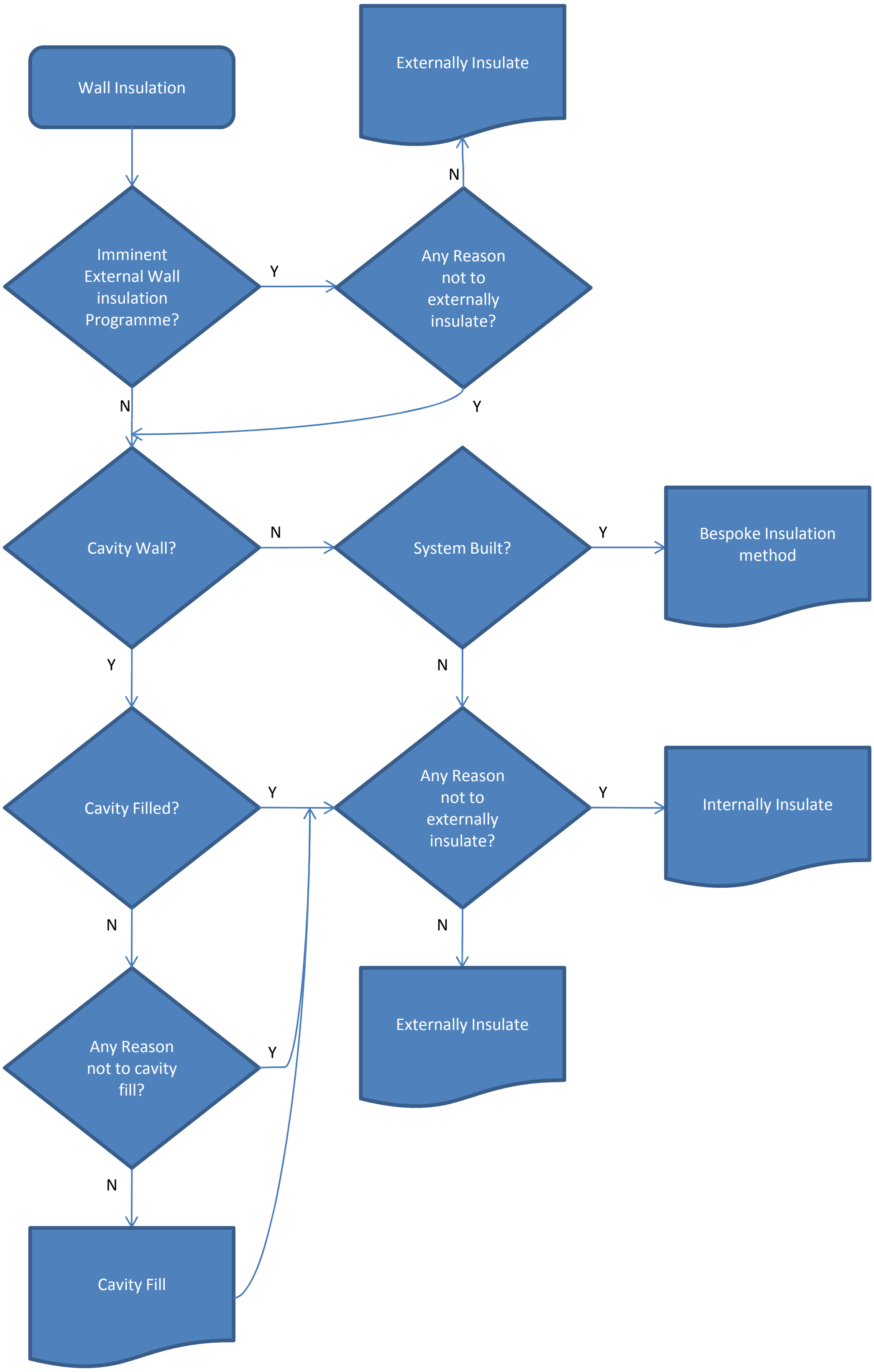
Where there is not an imminent programme of external wall insulation, cavity walls should be filled where possible. Properties built before 1930 should be taken on a case by case basis since cavity walls of this age are not generally filled due to difficulties assessing the suitability of the cavity for filling. Properties constructed after 1995 with a cavity construction are assumed to be filled. Using a thermal conductivity l=0.03 poly bead based blown insulant the resultant U-values are shown below:

Cavity Wall U-values: Cavity Fill			
	U-values (W/m^{2}K)		
Cavity Insulation	Unfilled	50mm	65mm
U-value	1.585	0.428	0.359

Building regulations part L1B 2010 require that a wall with internal or external insulation achieve a U-value of $0.55W/m^2K$. Although cavity wall fill insulation is a cost effective measure, and will result in warmer properties and in many cases diminish fuel poverty, the resultant u-values are not enough to maximise carbon savings. The addition of external wall insulation of phenolic foam with a thermal conductivity of l=0.025 to walls to cavity walls will result in the following U-values being attained:

Cavity Wall U-values: External insulation and cavity fill		
	U-values (W/m^2K)	
External Insulation	50mm Filled Cavity	65mm Filled Cavity
0	0.428	0.359
100	0.175	0.164
150	0.138	0.132
200	0.116	0.111

As can be seen in the above tables, where a wall has increasing levels of external insulation the value of the existing cavity wall insulation is reduced to near zero. This is because the cold bridging effect of the wall ties is greater when insulation is present than when an air gap is left in place.



Wall Insulation decision flow chart

Roof Insulation

Pitched roofs with loft space

Loft insulation is the most cost effective insulation measure as it is so cheap to install. The maximum feasible level of insulation should be installed.

Mineral wool is the cheapest and most widely used insulation material for lofts. Where mineral wool is to be used a total thickness of 350mm to achieve a target U-value of 0.12 W/m^2K should be installed. It should be noted, however that a thickness of 350mm would lead to a significant loss of utility if the roof is used for storage - there is an argument to be made for thinner, albeit more expensive insulation if storage is a critical issue. Even recently insulated lofts should be revisited and topped-up. However, these lofts are of lower priority.

Building regulations part L1B 2010 require that a pitched roof with insulation at ceiling level achieve a U-value of $0.16W/m^2K$.

Roof U-values: loft insulation

Loft Insulation (mm)	Roof U-values (W/m^2K)
0	1.715
100	0.411
150	0.276
200	0.210
250	0.171
350	0.127

An alternative EPS based insulation can be used above the joists where loft boards are desired (e.g. for loft storage)

Loft hatches will need to be replaced with a proprietary insulated loft hatch or insulated and draughtproofed and any loft hatch lining replaced or extended to allow for the greater level of loft insulation. Rigid insulation materials such as EPS or phenolic foam can be used.

Flat roofs

Flat roofs can be internally or externally insulated (or both). External insulation is preferred since it is less disruptive to the tenant and greater thicknesses of insulation can be specified. Building regulations part L1B 2010 require that a flat roof achieve a U-value of 0.18W/m^{2}K, unless this created problems with load bearing capacity or upstand height.

The addition of external flat roof insulation of phenolic foam with a thermal conductivity of l=0.025 to a typical heat loss flat roofs will result in the following u-values being attained:

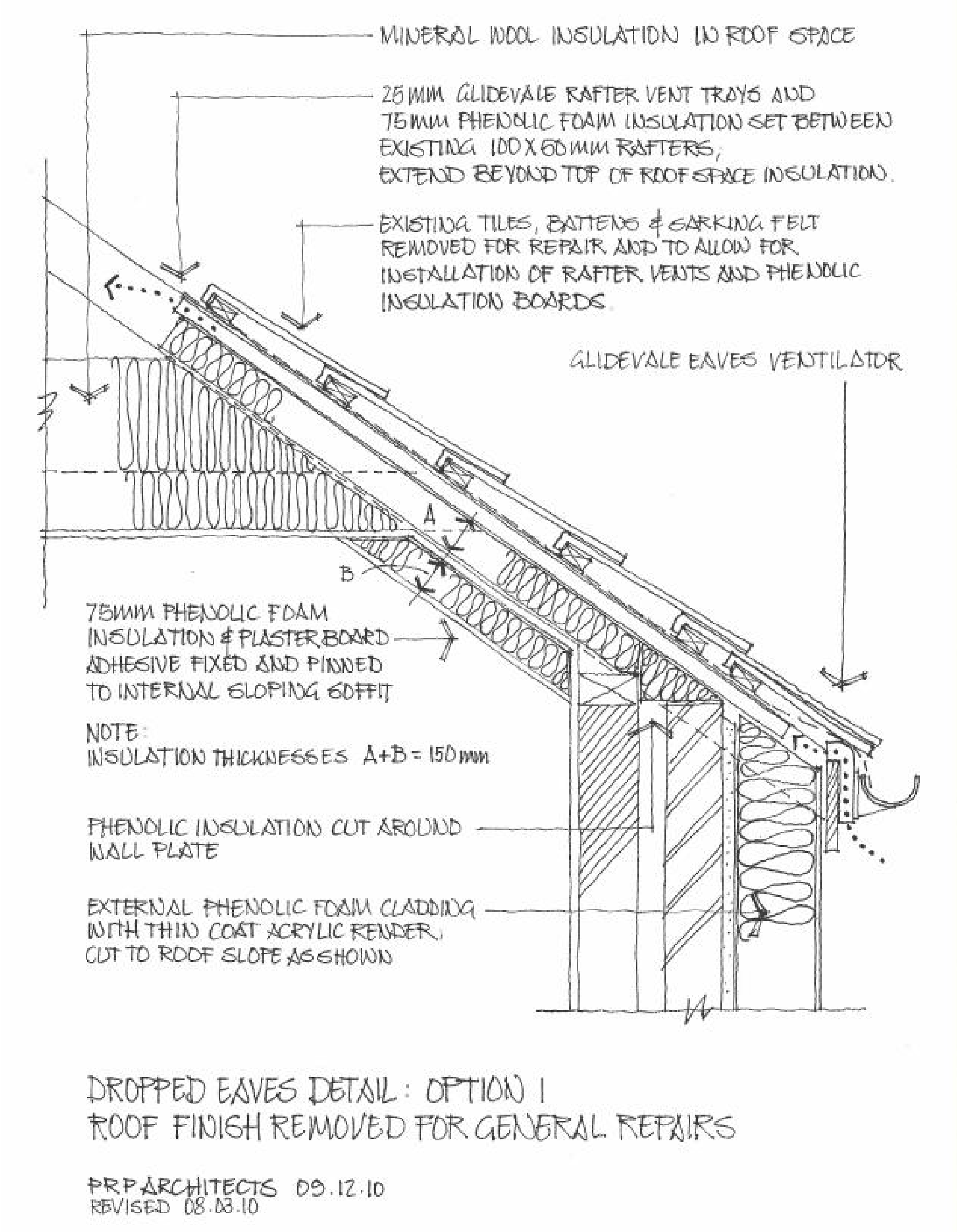
Roof U-values: flat roof external insulation	
Loft Insulation (mm)	Roof U-values (W/m^{2}K)
0	2.051
100	0.231
150	0.162
200	0.126

Sloping Ceilings / Warm Roofs

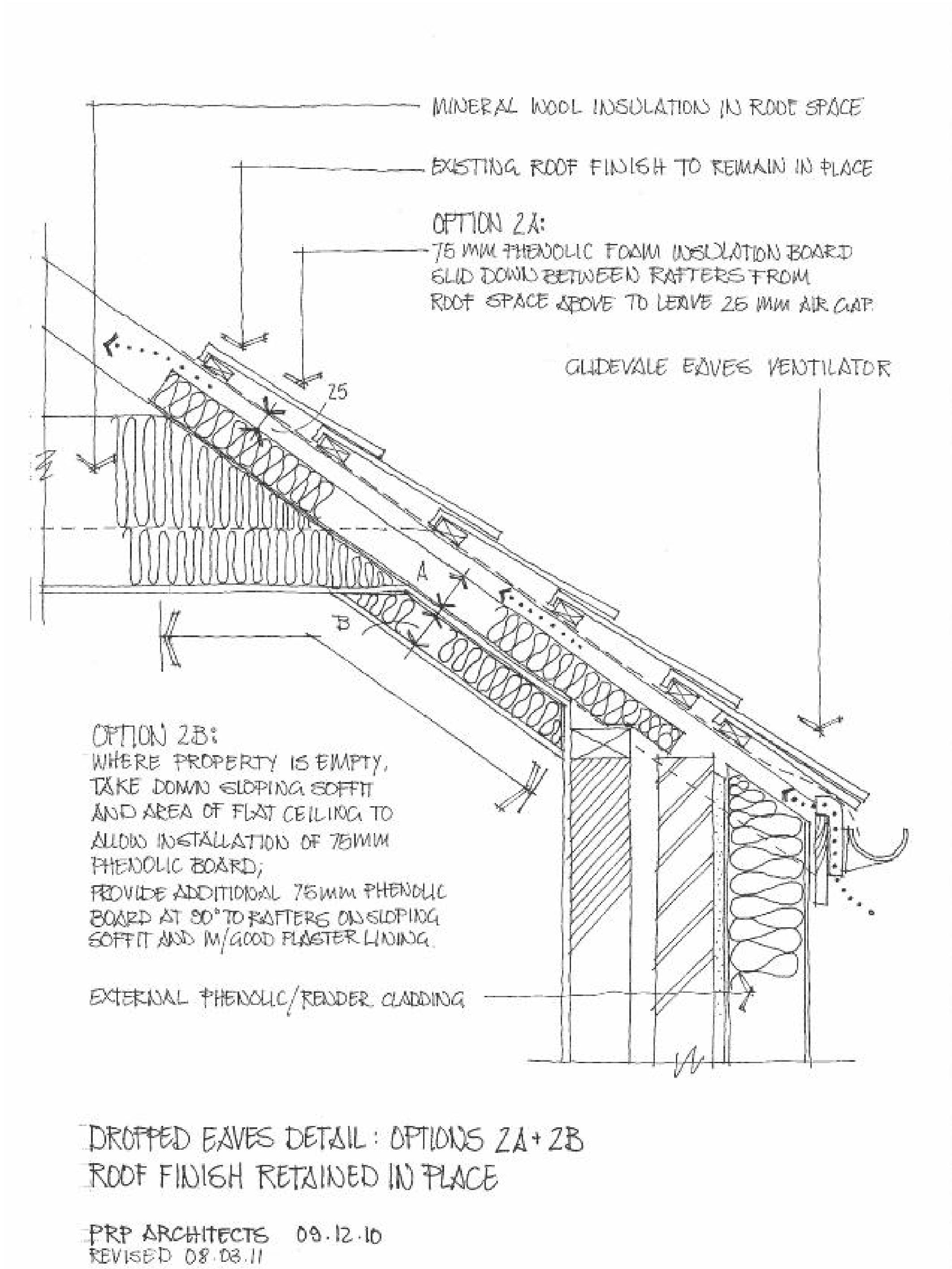
Where there is a room in the roof or 'dropped eaves', the sloping part of the ceiling will need to be insulated. This can be done either from the outside by removing the lower courses of slates or tiles and inserting phenolic foam with a thermal conductivity of l=0.025 between the rafters. A 25mm air gap will need to be left above the insulation if the roof space requires ventilation. (25mm only is required as rigid insulation will not expand to block the gap). Further insulated drylining should also be considered. The most effective method of insulating sloping ceilings is from the inside removing the plasterboard and inserting rigid phenolic foam based insulation both between and below the rafters.

Building regulations part L1B 2010 require that a pitched roof with insulation between rafters achieve a U-value of 0.18 W/m^{2}K. Where this is impractical due to headroom limitations a lesser provision of the best attainable U-value using insulation between rafters is allowable.

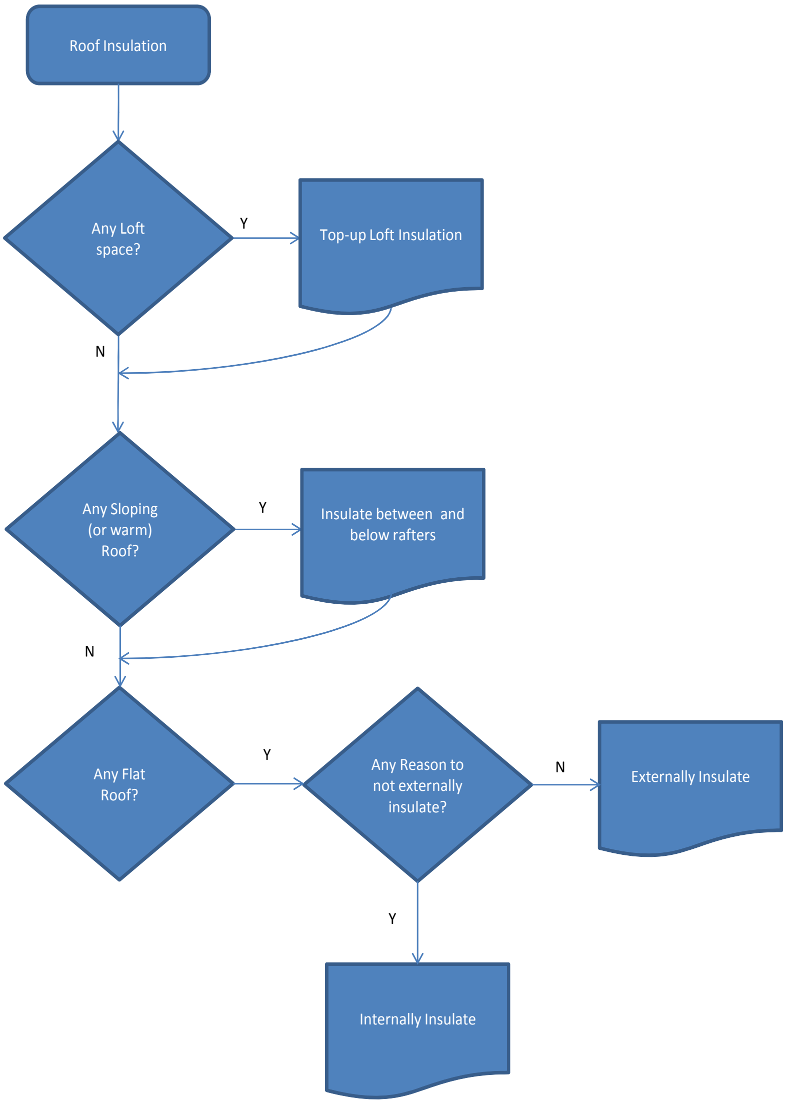
Roof U-values: **sloping roof insulation between and below rafters**	
Loft Insulation (mm)	Roof U-values (W/m²K)
0mm	3.002
75mm between rafters	0.390
75mm between rafters +75mm below rafters	0.175



Sloping roof insulation detail - option 1



Sloping roof insulation detail - option 2



Roof Insulation decision flow chart

FLOOR INSULATION

Suspended timber ground floors.

In practical terms insulating a suspended timber floor is the simplest floor type to insulate. Although lifting floorboards to gain access to the joists will be necessary and potentially disruptive, provided the works are done in conjunction with other 'trigger works' this difficulty is minimised.

The addition of 150mm of phenolic foam with a thermal conductivity of l=0.025 between floor joists to a typical heat loss suspended timber floor will result in the following U-value being attained:

Suspended timber floor U-value	
Insulation (mm)	Floor U-values (W/m^{2}K)
0	0.608
150	0.170

Building regulations part L1B 2010 require that a suspended timber floor with insulation between rafters achieve a U-value of 0.25 W/m^{2}K. Where this is impractical due to adjoining floor levels, a lesser provision of the best attainable U-value is allowable.

Solid ground floors

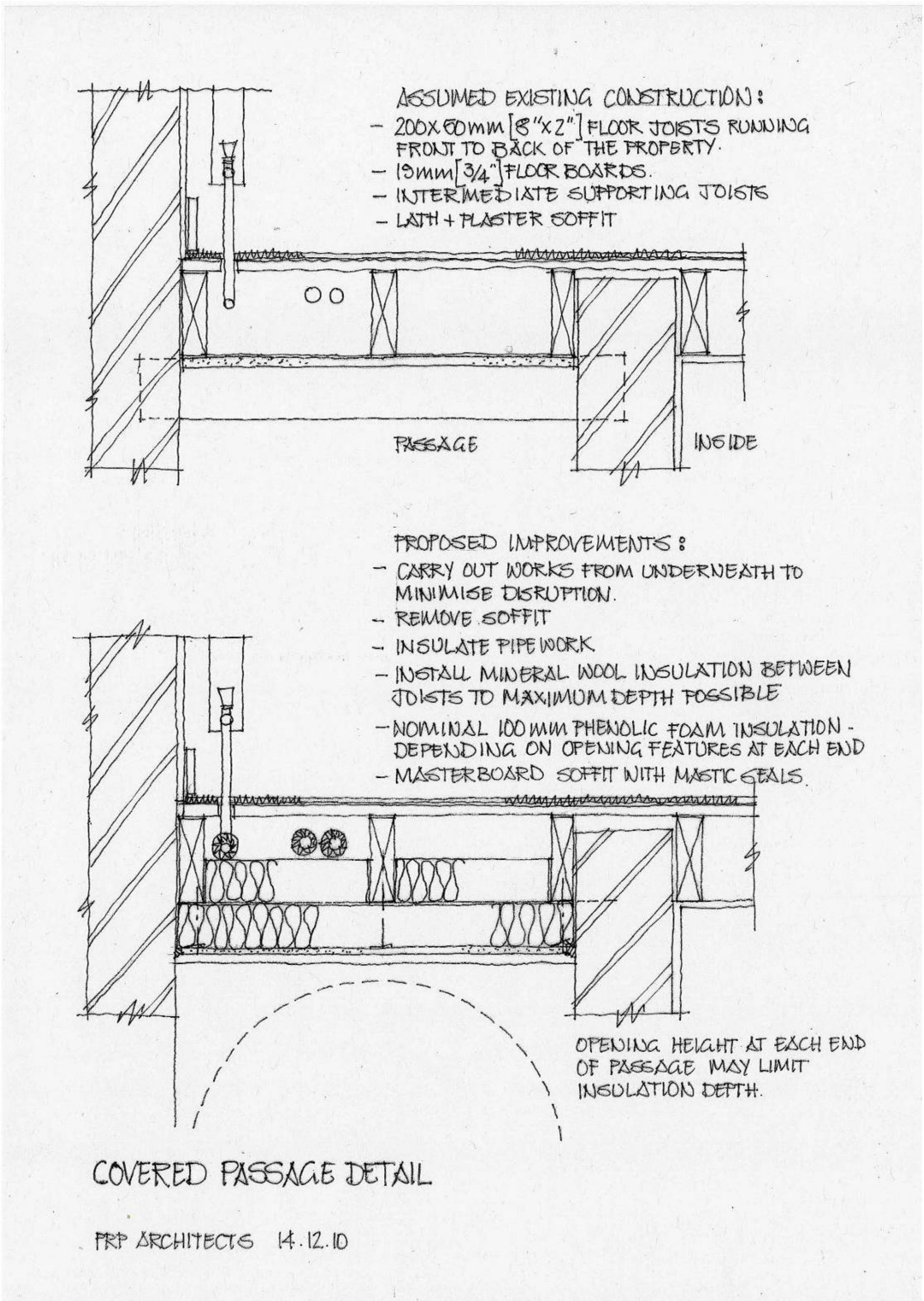
Solid heat loss floors in houses are currently very difficult to insulate since any additional floor height will not only result in necessary adjustments to doors, skirting and heat distribution systems, but also will make the lowest stair riser shorter than the next making the stairs difficult to use for tenants.

In flats with no stairs and solid floors it is worth investigating heat loss floor insulation by adding phenolic foam based insulation on top of the floor level and making necessary adjustments to doors etc. Digging out the screed and adding insulation may also be possible. Solid floor insulation is not currently being recommended as a priority, as ground floor U-values are likely to be approx 0.6 W/m^{2}K at present and cost per kg CO2 emission reduction will be high.

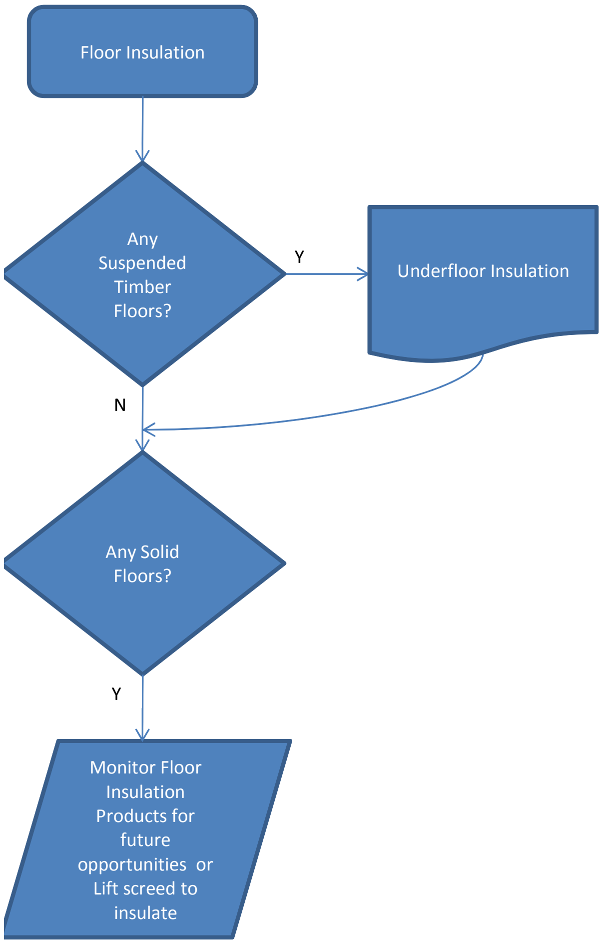
It is recommended that emerging technological solutions in this area be investigated periodically.

Soffits

Where the underside of a floor is open to external elements (e.g. above a passageway) It is likely to be a major heat loss route from a property. Regardless of the construction these types of floor should be insulated as a priority as problems such as condensation are common in the rooms immediately above.



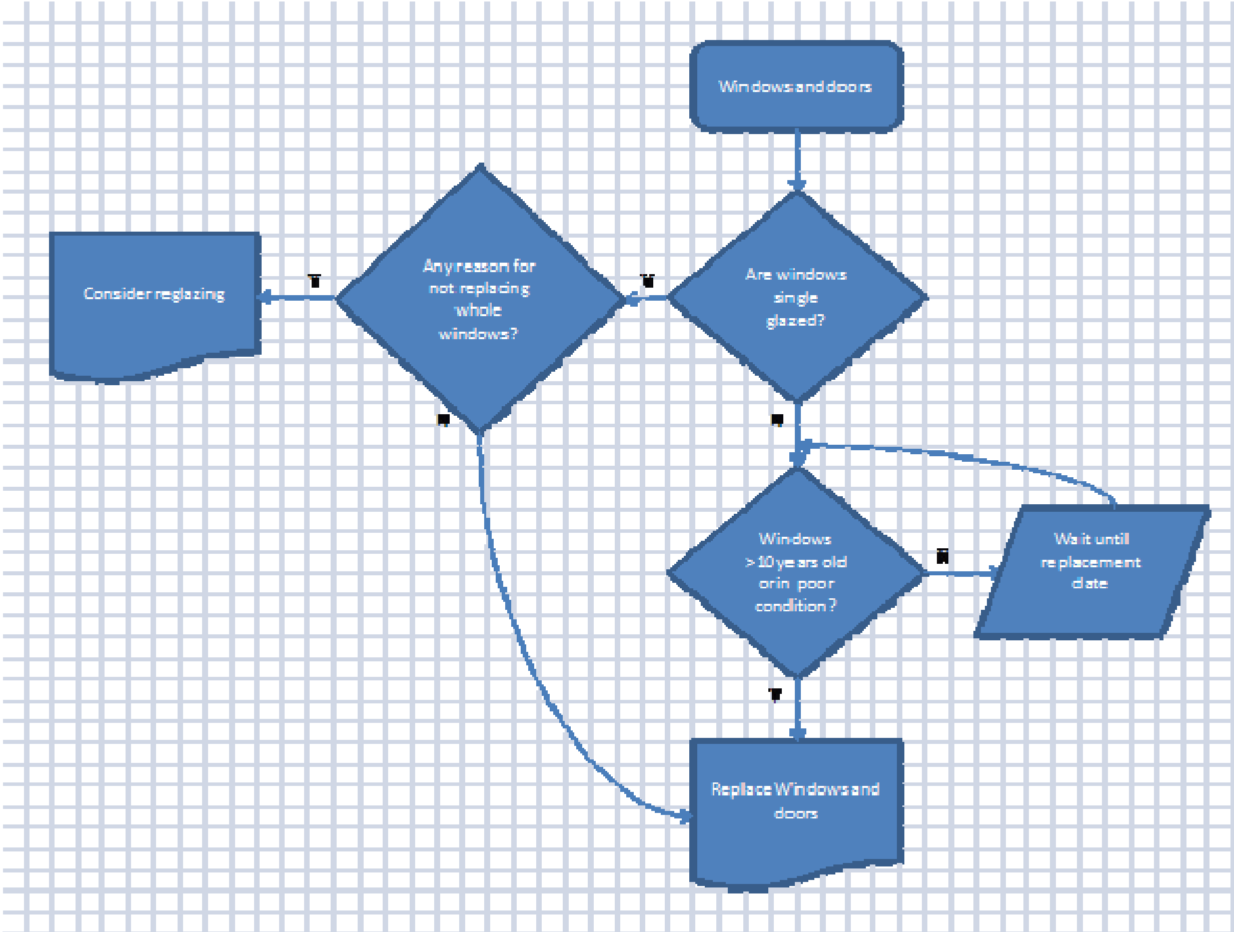
Covered Passage - soffit insulation



Floor Insulation decision flow chart

Windows and Doors

Door and window replacements are highly recommended for doors and windows that are in poor condition, particularly windows that are single glazed that are not in Listed buildings or conservation areas. Consideration should also be given to re-glazing existing frames with high specification double glazing. In practice this is likely to be 12mm Argon filled gap double glazing with low-e glass. Given the relatively short life of windows it is not considered necessary to install triple glazing.. The u-value of new windows should be 1.4W/m^{2}K - this will likely be 16mm Argon filled gap double glazing with low-e glass.



Windows and doors decision flow chart

HEATING SYSTEM UPGRADES

Specification

Where an existing gas central heating system is in place and the boiler is either non-condensing or at the end of its serviceable life, unless a solar thermal installation is considered feasible (see decision chart) a high specification condensing combi boiler should be installed. When a solar thermal system is a feasibility, consideration should be given to installation of a condensing system boiler with a new hot water cylinder that has capacity for dedicated solar thermal storage. The size of this tank will be dictated by the size of the solar thermal panel and physical constraints of the dwelling.

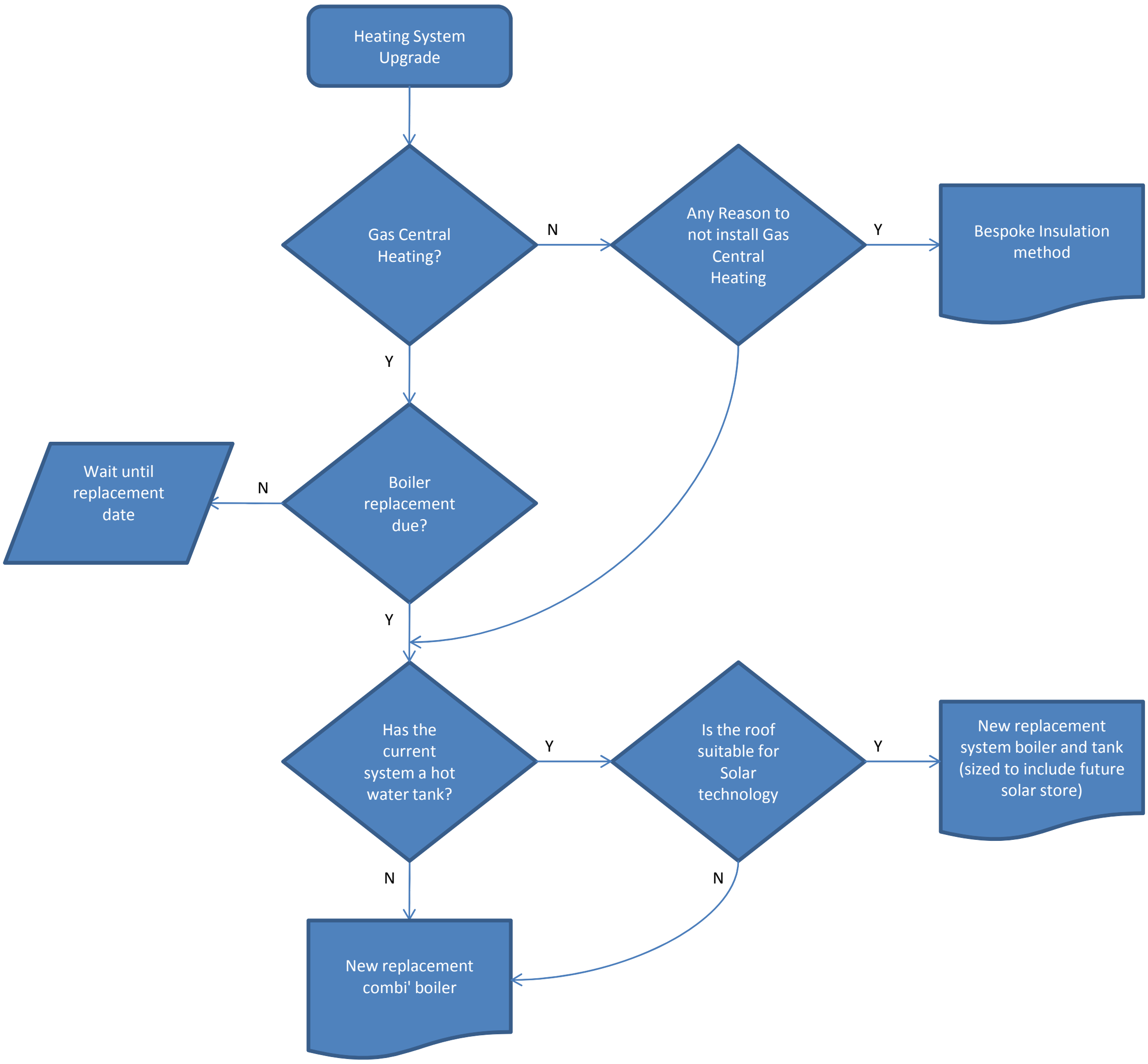
Heating System sizing

Care should be taken to ensure that any new heating system will not be oversized in a property that has high levels of insulation.

Wet Underfloor Heating

Underfloor heating consists of heat distribution pipes running under the floor. There are several advantages to underfloor heating over the more traditional radiator systems. Low temperature (runs at ~40oC) distributions systems are more efficient. This will be even more advantageous in well insulated buildings. Removal of radiators allow tenants access to presently unusable wall areas - this is especially advantageous where internal wall insulation must be used, and floor area is reduced by this.

Underfloor heating is particularly suitable for heat pump based heating systems as these are more efficient at lower temperatures; which although are not currently being recommended as part of a whole stock retrofit programme are likely over time to become market mature enough for consideration in suitable properties.



Heating system decision flow chart

Three-bedroom Semi-detached House

	EXISTING CONDITION	Issues and Risks
01 Chimneys, Flues and Stacks	• Chimney stacks are visually important to the appearance of a house • Potential for heat loss and damp penetration into the property	• Unknown condition of brickwork, flue, parging, soot/debris etc • Party wall issues • Consider options for making use of flue for ventilation etc.
02 Roof and Roof Space	• Usually insufficient insulation - risk of heat loss • Insufficient or irregular cross ventilation - risk of condensation	• Condition of slates / tiles, nails, flashings, etc; retain or re-roof? • Re-roof option: assessment of existing structure to accept new,

	• Eaves projection can vary widely • Storage of possessions / additional load on ceiling joists • Uninsulated water tanks and distribution pipework • Pitches vary • Low pitches restrict access into the eaves internally • Dropped eaves detail - difficult to insulate	possibly heavier finish • Re-roof option: achieving a satisfactory junction between new finish and adjoining roof • Introduction of ventilation at eaves and ridge levels • Eaves overhang: potential for extension to accept over-cladding • Capacity for roof structure to support new roof mounted technologies
03 Gable End Walls	• Exposed walls with potential for cold bridges at eaves and ceiling joist levels	• Legal issues arising from works to party walls, chimney stacks / flues etc. • Achieving a satisfactory visual / weathering detail if one property is over-clad and the other is not • Need to extend gable verge to accommodate over-cladding
04 Rainwater Goods	• Variety of materials and designs • Potential inadequate gutter sizes to cope with increased rainfall predictions • Potential cold bridges / damp penetration at downpipe fixing positions	• Possibility for increasing gutter size if eaves extended (relationship to window heads) • Issues arising from shared gutter / downpipe systems, particularly if one property is over-clad and the other is not • Practicality / cost of adapting drainage connections
05 External Walls	• Variety of construction methods and materials: solid/cavity brickwork, render, pebbledash, concrete panel etc. • Heat loss through the structure • Cold bridges at reveals • Risks of damp penetration through solid walls • Cracking / spalling of render • Cavity and cavity tie conditions not known • Cold bridge formed by recessed meter boxes • Cold bridge formed by cavity closers and wall ties	• Change of appearance / loss of detail if over-cladding is proposed • Choice of over-cladding insulation material / system • Potential for incorporating local materials and building traditions into any over-cladding proposal • Interface between new insulation and existing service pipes - need to reposition • Working around existing service pipe / drainage connections, both above and below ground • Loss of thermal mass if internal dry lining is used • Elimination of cold bridges at upper floor edges (eg: between joists) if over-cladding not used

06 Party Walls	• Internal party walls often poorly constructed and of varying thickness • Risk of damp penetration / heat loss at junctions with external walls • Risk of heat loss to adjacent property • Potential for limited sound insulation	• Potential to dry line internal party wall returns if adjacent property is not over-clad as well • Practicality of internal dry lining entire party wall if adjacent property is not upgraded
07 Recessed Elements (Doors)	• Cold bridge formed by external walls returning into the building footprint • Front door: probably single glazed, un-insulated, badly fitting and draughty • Cold bridge through first floor soffit to room above	• Front door replacement • Potential / desirability of creating a draught lobby
08 Projecting Elements (Bay Windows)	• Walls below bays often solid construction or single skin • Spandrel panels between ground and first floor bays often timber frame with no insulation • Footings often inadequate; risk of settlement • No access to pitched (or flat) roofs and no insulation • Potential for internal bressumer beams to deflect causing damage to roof finishes, damp penetration and draughts	• Options for improving thermal performance of walls • Dealing with structural stability issues / footings • Dealing with bressumer beam issues and cold bridges • Consider replacing small roofs with disproportionately large slates / tiles with flat roofs if over-cladding is proposed
09 Windows and Doors	• Windows are visually important to the appearance of a house • Variety of window styles, materials and mode of operation • Mixture of single and double glazing of varying age and condition • Often poorly fitting and draughty • Potential for condensation and mould growth • Variable condition and appearance • Risk of cold bridges via solid brick / stone sills	• Practicality / cost of reproducing original designs in upgraded form • Selection of alternative window design, material or mode of operation • Dealing with window replacement if over-cladding used: sub-frame, sill and reveal details • Position of the window in the wall relative to insulation (internal or external) - maintaining the thermal envelope and avoiding cold bridges • Opportunities to maximise internal daylight levels by varying

		window design / manufacture • Life expectancy / maintenance of the chosen system
10 **Floors**	• Solid floors - limited opportunity for insulation • Suspended floors - need to maintain cross ventilation can lead to draughts • Future proofing and adaptability issues to do with flooding and water ingress from under raised floors	• Options for insulating solid ground floors • Options / practicality of insulating suspended ground floors with residents in occupation • Insulating the external edge of ground floors in hard and soft landscape
11 **Service Penetrations**	• Potential for cold bridges at fixing positions • Potential for cold bridges, draughts and water penetration arounf poorly finished openings	• Consider ways to limit cold bridges
12 **Internal Areas**	• Heating and heat distribution • Ventilation • Water / fuel issues	• Practicality and limiting disruption when considering any internal works with residents in occupation

	IMPROVEMENT OPTIONS	Innovation Ideas
01 Chimneys, Flues and Stacks	• Sweep, clear, fill with insulation and cap • Utilise for natural or fan assisted ventilation / heat recovery	• Look at the potential for traditional spinners and/or hooded cowls to generate up-draught • Kit of parts needed, including flue liners, fans, grilles, heat recovery, etc.
02 Roof and Roof Space	• Opportunity to replace roof finish to give 60 years life • Integrate PV tiles with new / existing tiles • Integrate effective roof space ventilation with insulation • Roof mounted technologies: solar and PV	• Develop a simple and reliable eaves/rafter vent system that can be installed internally - possibly a rigid eps board with vent 'grooves' in the top surface • Look at lighter and slimmer PV/solar thermal units which are less visually intrusive

<table>
<tr><th></th><th>IMPROVEMENT OPTIONS</th><th>Innovation Ideas</th></tr>
<tr><td></td><td>• Strengthen ceiling joists and create designated storage platforms above insulation
• Extend eaves to accommodate overcladding and/or larger gutters
• Extend gable verge to accommodate over-cladding
• Insulate dropped eaves detail</td><td>• Develop an inset 'flush' mounted panel detail
• Develop an alternative to quilt insulation which is thinner and incorporates a storage surface
• Develop a simple eaves extension adaptable to various roof pitches
• Develop a simple verge extension adaptable to various roof pitches
• Develop eps board with vent grooves for dropped eaves condition</td></tr>
<tr><td>03 Gable End Walls</td><td>• Thinner external insulation that creates less of a step at a party wall
• Extend verge to accommodate external cladding</td><td></td></tr>
<tr><td>04 Rainwater Goods</td><td>• Incorporate enlarged gutters into eaves extension
• Enlarged gutters and downpipes to deal with increased rainfall and storms</td><td>• Develop an insulated fixing block for RWPS to sit within over-cladding to reduce cold bridge effect</td></tr>
<tr><td>05 External Walls</td><td>• External wall insulation with alternatives to render finish to increase variety and regional diversity; eg: weather boarding, tile hanging, mathematical tiles, etc.
• Insulate external window reveals
• Insulate the ground level slab edge
• Dry line where over-cladding would be inappropriate</td><td>• Develop thinner external insulation to minimise eaves overhang issue
• Develop thinner insulation to suit reveal detail
• Develop/identify replacement windows with thinner frame sizes to minimise daylight loss due to sub-frames
• Develop ways to locate new windows in a forward position in line with EWI to eliminate the reveal problem
• Alternatives to EWI: chemical treatment of brick structure to change its thermal conductivity (similar to Accoya wood)
• Develop a preformed / pre-finished insulated cladding panel to insulate ground slab edge below DPC level
• Develop wall mounted meter boxes with integral insulation to minimise cold bridge</td></tr>
</table>

	IMPROVEMENT OPTIONS	Innovation Ideas
06 **Party Walls**	• Dry line party walls where EWI is either not an option or is nor carried over the party line externally • Where EWI is not carried over the party line, dry line up to a suitable return such as a chimney breast or corner • Dry line all party wall surfaces where the adjacent property has not been upgraded	
07 **Recessed Elements (Doors)**	• Over-clad or dry line return walls • Remove ceiling within porch area, insulate between first floor joists and provide new ceiling • Option to provide new external door to form a draught lobby	• Develop thin external cladding where entrance width is limited; possibly nano-gel if weather protection is adequate
08 Projecting Elements (Bay Windows)	• Upgrade to window and walls as described in 09 and 05 • Strip and insulate spandrel panels where appropriate • Where over-cladding is proposed, remove pitched roof and renew with insulated flat roof	
09 **Windows and Doors**	• Repair and upgrade existing original windows where possible/desirable; refurbishment package to include reform or remake sashes to accommodate thin 12mm 'conservation' double glazing; provide new draught seals, improve air-tightness • Selection of new window type in a style and fenestration pattern suitable to the dwelling and to maximise daylight • Thermally broken double glazed units; triple glazed where appropriate • Consider junction with either external cladding or internal dry lining to allow future replacement • Reposition windows to ensure continuity of insulation and eliminate cold bridges • Long maintenance period materials • Extend sills to accommodate over-cladding	• Develop / encourage suppliers to manufacture alternative thin and economical double glazing to fit into existing frames • Develop thinner profile window frames to compensate for reduced glass area where sub-frames are used

	IMPROVEMENT OPTIONS	Innovation Ideas
10 Floors	• Solid floors: insulate slab edge externally as in 05 above • Solid floors: insulate below timber floating floor finish	• Develop simple system for insulating below suspended timber floors
11 Service Penetrations	• Improve air tightness around pipe penetrations	
12 Internal Areas	• Consider heating systems • Heat recovery systems • Water / fuel • Range of dynamic controls for heating and lighting - movement sensors	• Develop systems for retrofit under floor heating • Develop small scale single dwelling / single probe heat pumps • Consider dynamic insulation

Mid-Rise Apartment

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	EXISTING CONDITION	Issues and Risks
01 Chimneys, Flues and Stacks	• Stacks in flats often used for boiler or gas fire flues • Chimney stacks are visually important to the appearance of a building • Potential for heat loss and damp penetration where unused and left open	• Unknown condition of brickwork, flue, parging, soot/debris etc • Party wall issues • Consider options for making use of flue for ventilation etc.
02 Roof and Roof Space	• Un-insulated soffits over recessed balconies • Usually insufficient insulation - risk of heat loss • Insufficient or irregular cross ventilation - risk of condensation • Eaves projection can vary widely • Storage of possessions / additional load on ceiling joists • Uninsulated water tanks and distribution pipework • Pitches can vary, but often quite low	• Roof space access possibly more complicated due to single hatch position over stair well or tank room • Condition of slates / tiles, nails, flashings, etc; retain or re-roof? • Re-roof option: assessment of existing structure to accept new, possibly heavier finish • Introduction of ventilation at eaves and ridge levels • Eaves overhang: potential for

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
	• Low pitches restrict access into the eaves internally	extension to accept over-cladding • Capacity for roof structure to support new roof mounted technologies
03 Gable End Walls	• Exposed walls with potential for cold bridges at eaves and ceiling joist levels	• Gable verge overhang: potential for extension to accept over-cladding
04 Rainwater Goods	• Variety of materials and designs • Potential inadequate gutter sizes to cope with increased rainfall predictions • Potential cold bridges / damp penetration at downpipe fixing positions	• Possibility for increasing gutter size if eaves extended (relationship to window heads) • Practicality / cost of adapting drainage connections
05 External Walls	• Variety of construction methods and materials: solid/cavity brick & blockwork, render, pebbledash, concrete panel etc. • Heat loss through the structure • Cold bridges at reveals • Cold bridges formed by expressed concrete floor slabs and projecting concrete balconies • Risks of damp penetration through solid walls • Cracking / spalling of render • Cracking and spalling of concrete • Cavity and cavity tie conditions not known • Cold bridge formed by cavity closers and wall ties • Potential cold bridge through externally expressed party walls	• Change of appearance / loss of detail if over-cladding is proposed • Choice of over-cladding insulation material / system - larger areas / greater impact • Potential for incorporating local materials and building traditions into any over-cladding proposal • Interface between new insulation and existing service pipes - need to reposition • Working around existing service pipe / drainage connections, both above and below ground • Loss of thermal mass if internal dry lining is used • Elimination of cold bridges at upper floor edges (expressed externally or not) if over-cladding is not used • Practicality of dry lining entire properties • Access for thermal improvement and window replacement in high rise blocks

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
06 **Party Walls**	• Internal party walls often poorly constructed and of varying thickness • Risk of damp penetration / heat loss at junctions with external walls • Risk of heat loss to adjacent property • Potential for limited sound insulation • Heat loss through walls adjacent to unheated common halls and stair wells	• Potential to dry line internal party wall returns if over-cladding is not used • Practicality of dry lining entire properties • Leasehold issues arising from works to party walls, chimney stacks / flues etc.
07 **Recessed Elements (Balconies)**	• Cold bridge formed by external walls returning into the building footprint • Cold bridge formed by concrete slabs extending back into the building • Cold bridge formed where access decks and/or balconies placed over habitable rooms	• Potential / desirability of creating an enclosed winter garden • Practicality of insulating above and below the slab; threshold heights • Insulation detail over habitable rooms
08 Projecting Elements (Balconies)	• Cold bridges formed by projecting concrete balcony slabs • Potential for drainage issues depending on size	• Practicality of removing / replacing with new to include structural thermal break separation • Enclosure to form winter garden; structural strength / alternative support
09 **Windows and Doors**	• Windows are visually important to the appearance of a building • Variety of window styles, materials and mode of operation, often due to leaseholders changing their windows without regard to the original design concept • Mixture of single and double glazing of varying age and condition • Often poorly fitting and draughty • Potential for condensation and mould growth • Variable condition and appearance • Risk of cold bridge via solid brick or stone sills • Risk of cold bridge via concrete	• Practicality / cost of reproducing original designs in upgraded form • Selection of alternative window design, material or mode of operation • Dealing with window replacement if over-cladding used: sub-frame, sill and reveal details • Practicality of window replacement from inside in multistorey blocks • Position of the window in the wall relative to insulation (internal or external) - maintaining the thermal

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
	lintels and/or window surrounds	envelope and avoiding cold bridges • Opportunities to maximise internal daylight levels by varying window design / manufacture • Life expectancy / maintenance of the chosen system
10 **Floors**	• Solid ground floors - limited opportunity for insulation • Suspended timber floors in flats are not common • Suspended concrete ground floors are sometimes found on sloping sites - need to maintain cross ventilation • Adaptability - issues to do with flooding and water ingress from under suspended floors • Concrete upper floors are common in flats; issues to do with cold bridges at balconies and common parts, also sound transmission	• Options for insulating solid ground floors • Options / practicality of insulating suspended ground floors with residents in occupation • Insulating the external edge of ground floors in hard and soft landscape
11 **Service Penetrations**	• Potential for cold bridges at fixing positions • Potential for cold bridges, draughts and water penetration around poorly finished openings • Flats often have centralised internal shared service cores	• Consider ways to limit cold bridges
12 **Internal Areas**	• Heating and heat distribution • Communal heating systems • Ventilation - usually only cross ventilation • Water / fuel issues	• Practicality and limiting disruption when considering any internal works with residents in occupation
13 **Common Areas**		• Practicality of insulating walls onto common areas and stairs without reducing width

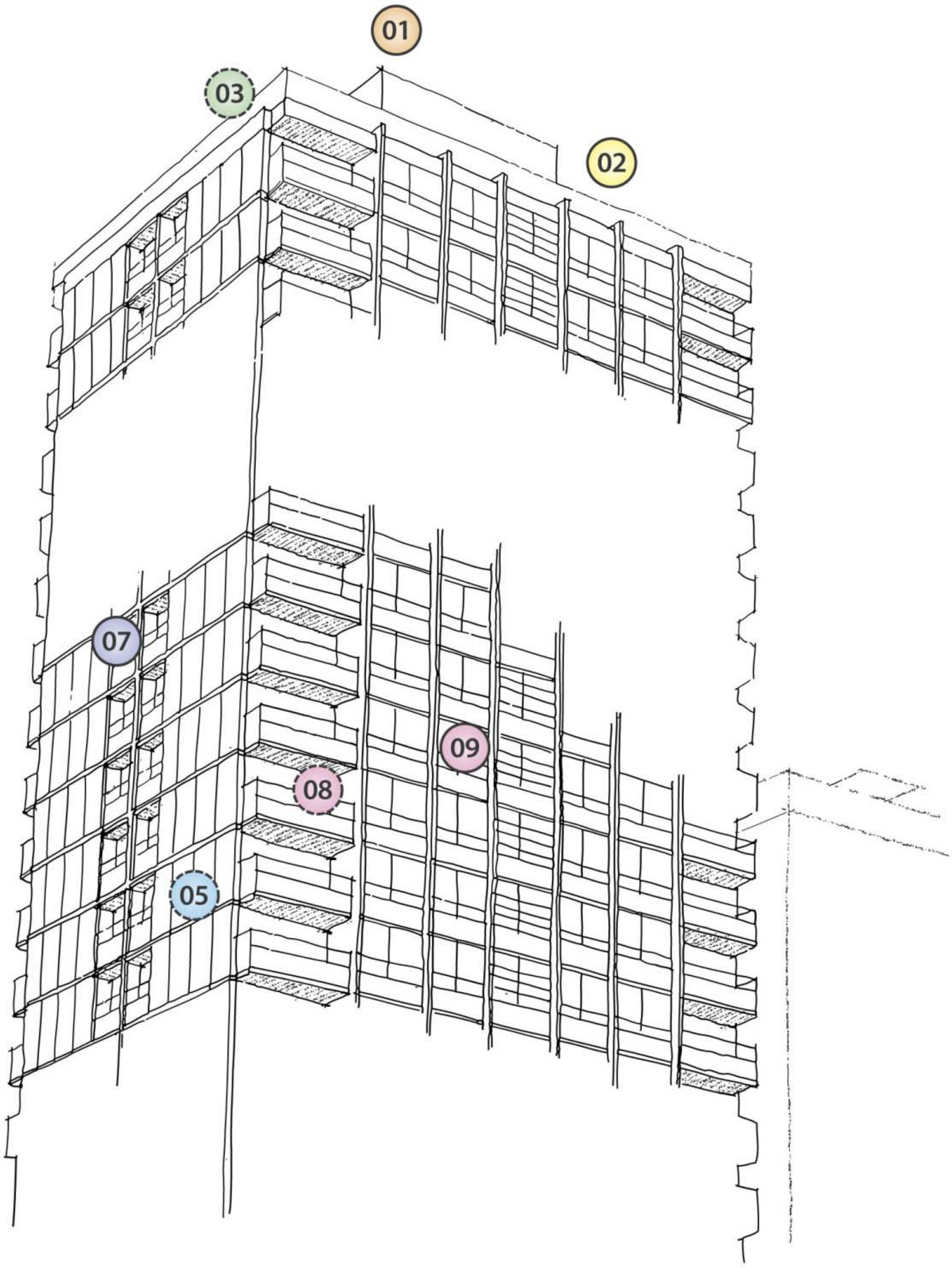
(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Ideas**
01 Chimneys, Flues and Stacks	• Sweep, clear, fill with insulation and cap • Utilise for natural or fan assisted ventilation / heat recovery	• Look at the potential for traditional spinners and/or hooded cowls to generate up-draught • Kit of parts needed, including flue liners, fans, grilles, heat recovery, etc.
02 Roof and Roof Space	• Opportunity to replace roof finish to give 60 years life • Integrate PV tiles with new / existing tiles • Integrate effective roof space ventilation • Roof mounted technologies: solar and PV • Extend eaves to accommodate over-cladding and/or larger gutters • Extend gable verge to accommodate over-cladding • Insulate dropped eaves detail	• Look at lighter and slimmer PV/solar thermal units which are less visually intrusive • Develop a simple and reliable eaves/rafter vent system that can be installed internally - possibly a rigid eps board with vent 'grooves' in the top surface • Develop an inset 'flush' mounted panel detail • Develop a simple eaves extension adaptable to various roof pitches • Develop a simple verge extension adaptable to various roof pitches • Develop eps board with vent grooves for dropped eaves condition

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Ideas**
03 Gable End Walls	• Thinner external insulation that minimises need to extend eaves • Extend verge to accommodate external cladding	
04 Rainwater Goods	• Incorporate enlarged gutters into eaves extension to address adaptability issues	• Develop an insulated fixing block for RWPS (or other services) to sit within over-cladding to reduce cold bridge effect
05 External Walls	• External wall insulation with alternatives to render finish to increase variety and regional diversity; eg: weather boarding, tile hanging, mathematical tiles, etc. • Insulate external window reveals • Insulate the ground level slab edge • Dry line where over-cladding would be inappropriate	• Develop thinner external insulation to minimise eaves overhang issue • Develop thinner insulation to suit reveal detail • Develop/identify replacement windows with thinner frame sizes to minimise daylight loss due to sub-frames • Develop ways to locate new windows in a forward position in line with EWI to eliminate the reveal problem • Alternatives to EWI: treatment of brick structure to change its thermal conductivity (similar to Accoya wood) • Develop a preformed / pre-finished insulated cladding panel to insulate ground slab edge below DPC level • Develop wall mounted meter boxes with integral insulation to minimise cold bridge • Develop ways to insulate upper level concrete floor edges (expressed externally or not) where dry lining is used
06 Party Walls	• Insulate internal party walls between heated flats and unheated common areas • Return dry-lining along party walls to minimise cold bridges where whole wall dry-lining is used • Insulate cavity party walls	• Develop thin insulation to minimise reduced stair widths • Develop simple ways to increase stair widths reduced by insulation • Develop effective cavity party wall insulation product/process

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Ideas**
07 Recessed Elements (Balconies)	• Insulate return walls and soffits • Enclose balconies to form winter gardens / sheltered spaces	• Develop detail for insulating over habitable rooms
08 Projecting Elements (Balconies)	• Insulate above and below projecting structure • Remove projecting structure and replace with bolt-on balcony with thermal break • Enclose balconies to form individual winter gardens	• Develop ways to enclose whole facades as a shared winter garden / sheltered space
09 Windows and Doors	• Repair and upgrade existing original windows where possible/desirable; refurbishment package to include reform or remake sashes to accommodate thin 12mm 'conservation' double glazing; provide new draught seals, improve air-tightness • Selection of new window type in a style and fenestration pattern suitable to the dwelling and to maximise daylight • Thermally broken double glazed units; triple glazed where appropriate • Consider junction with either external cladding or internal dry lining to allow future replacement • Reposition windows to ensure continuity of insulation and eliminate cold bridges • Long maintenance period materials • Extend sills to accommodate over-cladding	• Develop thinner, less expensive double glazed units • Develop thinner profile window sections where glass area is reduced due to sub-frames
10 Floors	• Solid floors: insulate slab edge externally as in 05 above	• Develop simple system for insulating below suspended concrete ground floors with under floor ventilation / air bricks; e.g. buildings on sloping sites
11 Service Penetrations	• Improve air tightness around pipe penetrations	

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Ideas**
12 **Internal Areas**	• Consider appropriate heating systems • Alternatives to traditional radiator systems; possibly skirting heating • Heat recovery systems • Water • Fuel • Range of dynamic controls for heating and lighting - movement sensors etc.	• Develop systems for retrofit under floor heating • Develop small scale single dwelling / single probe heat pumps • Consider dynamic insulation
13 **Common Areas**	• Address cold bridge from unheated common areas • Replace entrance doors with new with improved seals • Provide additional internal door to form draught lobby • Extend common parts externally to form draught lobby • Adapt common areas / stair wells to maximise solar heat gain and passive stack ventilation • Use roof mounted solar / PV to serve common parts • Provide solar/LED common area lighting	

High Rise Tower Block



(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
01 Chimneys, Flues, Stacks and Lift Shafts	• Flues and chutes from old incinerator units or communal ventilation systems often left open even when disused and can be difficult to remove • Refuse chutes discharge to air at roof level • Potential for heat loss and damp penetration where unused and left open • Lift shafts: potential for cold bridge from extended shafts and motor rooms at roof level • Lift shafts: potential chimney effect drawing warm air out of the building	• Unknown condition of flues and surrounding structure • Flues can often be asbestos • Party wall issues from cast-in flues and shafts between flats • Sound transmission from communal systems, particularly refuse chutes. • Difficulties associated with taking lifts out of service in high rise blocks in order to address thermal/acoustic issues within the shaft
02 Roof and Roof Space	• Usually concrete with poor thermal performance • Usually insufficient insulation - risk of heat loss • Potential for leakage where roof finish meets parapet and around service penetrations, cradle fixing points etc. • Coldest part of the building, maximum exposure • Un-insulated water tanks/service installations; lagging to distribution pipework often damaged and allowing water ingress • Roofs are generally flat; parapet heights can vary	• Condition of asphalt or other roof finishes • Condition of roof mounted services - water, oil, etc, and condition of pipework • Inadequate insulation to service runs across roofs • Re-roof option: assessment of existing structure to accept new finish and parapets to accept increased upstand height • Risk of damage to finishes and structure arising from maintenance access to roof mounted technologies, particularly aerials, mobile phone masts and flood lights • Capacity for roof structure to support new roof mounted technologies
03 Gable End Walls	• Parapets can act as significant cold bridges • Potential for extreme exposure of walls on all sides • Potential for degradation of materials	• Condition, height and stability • Ability to support new cladding systems

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
04 Rainwater Goods	• Usually internal and often cast iron • Built-in or cast-in pipes can leak - damage to structure and finishes • Blockages at roof level can lead to significant ponding creating a severely cold roof • Potential cold bridges/damp penetration at downpipe positions	• Repair or replacement of cast-in pipes - age / condition/ expected life • Need to increase sizes to allow for adaptability and increased rainfall • Practicality / cost of adapting drainage connections
05 External Walls	• Potential for extreme exposure of walls on all sides; worse at height • Construction methods and systems vary considerably • Exposed concrete frames cause huge cold bridges • Panel systems can leak causing damage to structure, increased cold bridge and damage to internal finishes • Variety of construction methods and materials: concrete frame with infill, concrete panel, steel frame, panel cladding systems, combinations of materials with differing thermal performance. • Heat loss through the structure • Cold bridges at reveals, material junctions • Cold bridges around precast window cladding panels • Minimal / zero insulation in early designs • Cold bridges formed by expressed concrete floor slabs and projecting concrete balconies • Risks of damp penetration through solid walls • Cracking and spalling of internal finishes • Cracking and spalling of concrete • Condition of system securing straps / bolts / brackets not known; often corroded • Cold bridge formed at balcony reveals and window junctions • Potential cold bridge through	• Stability, condition and life expectancy of existing structure may influence cladding options, particularly with panel system buildings • Availability of adequate fixing points • Change of appearance / loss of detail if over-cladding is proposed • Choice of over-cladding system - larger areas = greater visual impact • Accommodating extract fans and flues through the cladding • Loss of thermal mass if internal dry lining is used • Continued degradation of the structure if dry lining used • Cold bridge at floor edges (whether expressed externally or not) remain unresolved if over-cladding is not used • Access for initial thermal improvement and window replacement works, plus future maintenance at height and in exposed conditions

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
	externally expressed party walls	
06 Party Walls	• Internal party walls often solid concrete and of varying thickness • Risk of damp penetration and heat loss at junctions with external walls • Risk of heat loss to adjacent property • Risk of heat loss to a neighbour's external balcony • Generally poor sound insulation • Heat loss through walls adjacent to unheated common halls, landings and stair wells	• Potential to dry line internal party wall returns whether over-cladding is used or not • Practicality of dry lining against common parts or shafts, eg: lifts
07 Recessed Elements (Balconies)	• Cold bridge formed by external walls returning into the building • Cold bridge formed by concrete slabs extending back into the building • Cold bridge formed where access decks and/or balconies placed over habitable rooms • Often underused due to pigeon problems	• Potential/desirability of creating an enclosed winter garden • Larger buildings & greater numbers of people may make agreement on w/gardens difficult to achieve • Practicality of insulating above and below the slab; threshold heights, rainwater outlets, etc. • Insulation detail where recess is over a habitable room • Option to incorporate the balcony into the flat to make it bigger • Standards on amenity space per dwelling
08 Projecting Elements (Balconies)	• Cold bridges formed by projecting concrete balcony slabs and balustrades • Potential for drainage issues depending on size • Poor thermal performance of balcony access doors	• Practicality of removing and replacing existing balconies with new 'bolt-on' design incorporating structural thermal break separation • Enclosure to form winter garden; structural strength / alternative support • Achieving agreement • Change of image • Practicality of insulating if existing design retained
09 Windows and Doors	• Windows are visually important to the appearance of a building • Variety of window styles, materials and mode of operation	• Opportunity for alternative window design, material or mode of operation • Dealing with window

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
	• Difficulty of cleaning when at high level • Mixture of single and double glazing of varying age and condition • Often poorly fitting and draughty, particularly at high level • Potential for condensation and mould growth • Variable condition and appearance • Risk of water penetration due to degradation of mastic seals • Risk of cold bridge via frames and window surrounds	replacement if over-cladding used: sub-frame, sill and reveal details • Practicality of window replacement from inside in high rise blocks • Position of the window in the wall relative to insulation (internal or external) - maintaining the thermal envelope and avoiding cold bridges • Ensuring windows are installed as part of full envelope upgrade • Replacement window frames often thicker and more bulky than the existing; choice of material and varying the design can maximise glass area and daylight penetration • Life expectancy & maintenance requirements of the chosen system • Background ventilation if trickle vents not included – MVHR?
10 **Floors**	• Solid ground floors or floors over service areas usually un-insulated • Suspended concrete ground floors are sometimes found on sloping sites - need to maintain cross ventilation • Adaptability - issues to do with flooding and water ingress under suspended floors • Concrete upper floors are common in flats; issues to do with cold bridges at balconies and common parts, also sound transmission	• Options for insulating solid ground floors, or lowest level floors • Insulating the external edge of ground and upper floors
11 **Service Penetrations**	• Potential for cold bridges at fixing positions • Potential for cold bridges, draughts and water penetration around poorly finished openings • Flats often have centralised internal shared service cores	• Consider ways to limit cold bridges

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
12 **Internal Areas**	• Heating and heat distribution • Communal heating systems • Ventilation - usually only cross ventilation • Water / fuel issues	• Practicality and limiting disruption when considering any internal works with residents in occupation
13 **Common Areas**	• Usually unheated • Sometimes well ventilated for reasons of fire and/or smoke control; AOVs get left open making areas even more cold • Difficulty of insulating stairs without reducing width	• Practicality of insulating walls onto common areas and stairs without reducing width • Opportunities to use renewable technologies to serve common areas

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Potential**
01 Chimneys, Flues, Stacks and Lift Shafts	• Insulation around flues and shafts • Potential for natural or fan assisted ventilation / heat recovery • Improved insulation seals around lift doors and hatches • Energy efficient lift motors • Lift sequencing – lift does not return to ground every time	
02 Roof and Roof Space	• Replace roof finish to give 60 year life and incorporate insulation • Improve insulation to roof mounted	

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Potential**
	tanks and pipe runs • Roof mounted air source heat pump to heat common parts	
03 Gable End Walls	• Ensure parapets are included with external wall and roof insulation	
04 Rainwater Goods	• Rainwater collection for car washing, amenity space/communal landscape use • Rainwater discharge management via sumps, reed beds etc.	
05 External Walls	• External wall insulation with innovative finishes – bigger blocks make a bigger visual impact • Insulate exposed floor and wall slabs • Dry line where over-cladding would be inappropriate	• Develop thinner external insulation for recessed balcony returns, window reveals etc. • Develop/identify replacement windows with thinner frame sizes to minimise daylight loss due to sub-frames • Develop ways to locate new windows in a forward position in line with EWI to eliminate the reveal problem • Develop ways to insulate upper level concrete floor edges (expressed externally or not) where dry lining is used
06 Party Walls	• Insulate internal party walls between heated flats and unheated common areas • Return dry-lining along party walls to minimise cold bridges where whole wall dry-lining is used	• Develop thin insulation to minimise reduced stair widths • Develop simple ways to increase stair widths reduced by insulation
07 Recessed Elements (Balconies)	• Insulate return walls and soffits • Enclose balconies to form winter gardens / sheltered spaces	• Develop detail for insulating over habitable rooms
08 Projecting Elements (Balconies)	• Insulate above and below projecting structure • Remove projecting structure and replace with bolt-on balcony with thermal break • Enclose balconies to form individual winter gardens	• Develop ways to enclose whole facades as a shared winter garden / sheltered space

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Potential**
09 Windows and Doors	• Selection of new window type in a style and fenestration pattern suitable to the dwelling and sized to maximise daylight • Thermally broken double glazed units; triple glazed where appropriate • Consider option of reducing the glazed area where appropriate • Consider junction with either external cladding or internal dry lining to allow future replacement • Ensure continuity of the thermal envelope to eliminate cold bridges • Long maintenance period materials	• Develop thinner profile window sections where glass area is reduced due to sub-frames
10 Floors	• Solid floors: insulate slab edge externally as in 05 above • Insulate soffits above communal ground level areas, eg: entrance halls, pram stores, etc	
11 Service Penetrations	• Improve air tightness around pipe penetrations	
12 Internal Areas	• Consider alternative heating systems, eg: bio-mass or other district heating • Solar tracking PV brise soleil to each property serving common parts lighting • Individual room heat recovery fans • MVHR • Grey water recovery • Consider different technologies for different zones of a tall building determined by height or orientation, eg: ground source or seasonal storage for lower floors, PV for upper levels, etc - it doesn't have to be a whole building solution • Range of dynamic controls for heating and lighting - movement sensors etc.	
13 Common	• Address cold bridge from unheated common areas as above	•

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Potential**
Areas	• Replace block entrance doors with new with improved seals • Provide additional internal door to form draught lobby • Extend common parts externally to form draught lobby • Adapt common areas / stair wells to maximise solar heat gain and passive stack ventilation • Use roof mounted solar / PV to serve common parts • Provide fibre optic or LED common area lighting • Replace flat entrance doors with improved seals	

Hard To Treat

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
01 Chimneys, Flues and Stacks	• Chimney stacks are visually important to the appearance of a house, particularly in a property of historical or conservation area status • Potential for heat loss and damp penetration into the property • Older age may result in poorer condition • Risk of greater cold bridges from larger, more ornate, architecturally significant chimney stacks	• Unknown condition of brickwork, flue, parging, soot/debris etc • Party wall issues • Legal issues arising from works to party walls, chimney stacks / flues etc • Architectural significance may limit options for making use of flue for ventilation or dealing with cold bridges • Older age may result in poorer condition
02 Roof and Roof Space	• Usually insufficient insulation - risk of heat loss • Insufficient or irregular cross ventilation - risk of condensation • Eaves projection and design can vary widely, eg: gutters on rafter brackets (not fascia boards), decorative eaves supports, exposed rafter feet, cornices, etc • Storage of possessions/additional load on ceiling joists • Un-insulated water tanks • Pitches vary • Low pitches restrict access into the eaves internally • Dropped eaves detail - difficult to insulate • Non-standard timber sizes, sometimes un-squared timbers • Original, non-standard, possibly listed roof finishes which have to be retained or would be difficult to replace	• Condition of slates, tiles, nails, pegs, flashings, etc • Availability of matching materials for repair, working around roof technologies or total replacement • Re-roof option: assessment of existing structure to accept new, possibly heavier finish • Re-roof option: achieving a satisfactory junction between new finish and adjoining roof, particularly in a terrace • Introduction of ventilation at eaves and ridge levels • Eaves overhang: potential for extension to accept over-cladding where appropriate • Removal of old galvanised water tanks • Dormer windows with thin wall construction
03 Gable End Walls	• Exposed walls with potential for cold bridges at various levels • Various forms of construction, eg: timber frame • Decorative or architecturally sensitive wall finishes • Possibility of no party walls within the roof space	• Potential lack of party walls and effect on thermal performance • Need to extend gable verge to accommodate over-cladding

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
04 Rainwater Goods	• Variety of materials, designs and methods of support • Potential for inadequate gutter size to cope with increased rainfall predictions • Potential cold bridges/damp penetration at downpipe fixing positions • Old style cast iron or lead RWPs with little or no space behind	• Possibility for increasing gutter size if eaves extended (relationship to window heads) • Issues arising from shared gutter/downpipe systems, particularly if one property is over-clad and the other is not • Practicality / cost of adapting drainage connections • Replacing, matching, adapting architecturally significant rainwater goods and hoppers
05 External Walls	• Variety of construction methods and materials: solid/cavity brickwork, stone, render, timber frame, tile hanging, decorative elements, regional traditions/details, etc. • Heat loss through the structure • Cold bridges at reveals and stone window surrounds • Risks of damp penetration through solid walls • Cracking/spalling of render • Degradation of older materials • Cavity and cavity tie conditions not known • Cold bridge formed by cavity closers and wall ties	• Change of appearance and loss of detail from over-cladding is likely to limit if and where this can be done • Potential for incorporating local materials and traditions into any proposal • Interface between new insulation and existing service pipes - need to reposition • Working around existing service pipes and connections, both above and below ground • Loss of thermal mass if internal dry lining is used • Reduction of potentially small room sizes if dry lining is used • Reduction of options if neither external nor internal lining are possible • Elimination of cold bridges at upper floor edges if over-cladding not used • Risks to building fabric when old, draughty buildings are made warmer and more air tight • Risks arising from changing the balance of moisture absorption and evaporation, especially in timber framed buildings • Achieving a satisfactory visual/weathering detail if one property is over-clad and the

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
		other is not
06 Party Walls	• Internal party walls often poorly constructed and of varying thickness • Risk of damp penetration / heat loss at junctions with external walls • Risk of heat loss to adjacent property • Potential for limited sound insulation	• Potential to dry line internal party wall returns if adjacent property is not insulated • Practicality of internal dry lining entire party wall if adjacent property is not upgraded
07 Recessed Elements (Doors)	• Cold bridge formed by external walls returning into the building footprint • Front door: any window probably single glazed, un-insulated, badly fitting and draughty • Cold bridge through first floor soffit to room above	• Front door replacement; sourcing/procuring a suitable replacement • Options to insulate or improve the thermal performance of the existing door
08 Projecting Elements (Extensions and Bay Windows)	• Walls above/below bay windows often either solid single skin construction, or timber frame with tiles or render; rarely any insulation • Footings often inadequate; risk of settlement/pulling away from the facade • No access to pitched (or flat) roofs and no insulation • Potential for internal bressumer beams to deflect causing damage to roof and wall finishes, damp penetration and draughts • Similar problems with age/condition of windows and frames	• Options for improving thermal performance of wall elements • Dealing with structural stability issues/footings • Dealing with bressumer beam issues and cold bridges • Consider replacing small roofs with disproportionately large slates/tiles with flat roofs if over-cladding is proposed
09 Windows and Doors	• Windows are visually important to the appearance of a house • Variety of window styles, materials and mode of operation • Dormer windows more common • Mostly single glazed and of varying age and condition • Often poorly fitting and draughty • Potential for condensation and mould growth • Variable condition and appearance	• Practicality/cost of reproducing original designs in upgraded form • Selection of alternative window design, material or mode of operation • Opportunities to maximise internal daylight levels by varying window design • Life expectancy/maintenance of the chosen system

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**EXISTING CONDITION**	**Issues and Risks**
	• Risk of cold bridges via solid brick / stone sills	• Small windows limiting internal daylight levels • Potentially large areas of single glazing (such as in Modern Movement buildings) with high heat loss
10 **Floors**	• Solid floors - limited opportunity for insulation • Suspended floors - need to maintain cross ventilation can lead to draughts • Historically/contextually significant floor finishes, eg: oak boards, etc • Future proofing and adaptability issues to do with flooding and water ingress under raised floors • Floors over cellars	• Options for insulating solid ground floors • Options/practicality of insulating suspended ground floors with residents in occupation • Options for insulating floors over cellars • Options/implications of dry lining and insulating cellars • Insulating the external edge of ground floors in hard and soft landscape
11 **Service Penetrations**	• Potential for cold bridges at fixing positions • Potential for cold bridges, draughts and water penetration around poorly finished openings	• Consider ways to limit cold bridges • Limitations on options for service runs and fixings
12 **Internal Areas**	• Heating and heat distribution systems • Ventilation • Water / fuel issues	• Practicality and limiting disruption when considering any internal works with residents in occupation • Limitations on heat distribution systems in connection with historic or concrete floors • Impact of new heating on internal finishes, eg: wood panelling

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Ideas**
01 Chimneys, Flues and Stacks	• Sweep and clear flues, fill with insulation and cap • Utilise for natural or fan assisted ventilation	

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Ideas**
02 Roof and Roof Space	• Re-roof and consider solar thermal or PV where possible • Heritage/conservation roof lights for room-in-the-roof development, either as roof windows or linked to sun pipes or fibre optic lighting • Insulate roof space as either cold or warm roof • Ensure adequate roof space ventilation • Strengthen ceiling joists and create designated storage platform	
03 Gable End Walls	• Consider dry lining existing timber frame construction • Consider providing roof space party walls where none exist	
04 Rainwater Goods	• Enlarged gutters and downpipes where possible • Rainwater diverted and collected in water butt	
05 External Walls	• External wall insulation where possible, including local materials and details • Dry lining where internal conditions allow • Draught strip junctions between doors, windows and walls	• Investigate/consider 'insulating paint' • Insulating cornices at wall/ceiling junctions, particularly on upper floors
06 Party Walls	• Dry line where internal finishes allow	
07 Recessed Elements (Doors)	• Insulate externally where possible with thin, 16mm, insulation, including the soffit • Dry line internally • Provide additional internal thermal skin, such as a heavy curtain or fold-away internal shutters similar to traditional window shutters	
08 Projecting Elements (Bay Windows)	• Dry line wall elements where possible • Insulate flat roofs with parapets • In extreme circumstances, provide heavy curtains or shutters to screen off the recess on the inside during cold weather • Upgrade existing windows as in 09	

(Items in grey are ones that have previously been mentioned in Three-Bed Semi)	**IMPROVEMENT OPTIONS**	**Innovation Ideas**
09 **Windows and Doors**	• Repair and upgrade existing original windows where possible/desirable; refurbishment package to include reform or remake both fixed and opening lights to accommodate thin 12mm double glazing; provide new draught seals, improve air-tightness where appropriate • Selection of new window type in a style and fenestration pattern suitable to the dwelling and to maximise daylight • Consider secondary glazing • Thick curtains to minimise draughts	• Suppliers to develop thin double glazed units at reasonable cost to fit within existing rebates • Develop thinner profile window frames to minimise daylight loss
10 **Floors**	• Insulate suspended floors to rooms • Insulate floors over passages, tunnels and cellars • Thick carpets	• Develop simple system for insulating under suspended timber floors
11 **Service Penetrations**	• Improve air tightness around pipe penetrations	
12 **Internal Areas**	• Bio mass boiler • Micro CHP – suited to large 'leaky' house • Gas boiler flue gas heat recovery • eTRV's which respond to room temperature • Dynamic/motion sensor radiator controls – make sure the heat is where you want it, when you want it • Automatic radiator bleed valves to ensure radiators work to their maximum efficiency • Skirting heating if radiators cannot be used • Waste water heat recovery • Green tariff energy • Individual room heat recovery fans • LED or fibre optic lighting, such as Parans • Energy efficient white goods • Green switch to turnoff stand by equipment	

Costing Exercise:
Three Bedroom Semi-Detached

Some of the previous work for the OTEoEH project involved the costing of individual solutions for retrofit. While this gave us an idea of the relative costs of things and the relationship between materials and labour for the various technical solutions, it was widely recognized that package-based costing would have to be carried out in order to maximize the synergies between installing certain solutions together, as was demonstrated by the synergy matrices. We have carried out the exercise on the most common house type, the three-bedroom semi-detached property. The estimates given below refer to a 1919-1944 semi detached property with a bay window.

The costs cited below reflect current supply chain pricing methodology - a piecemeal, non-integrated approach that is in no way industrialised or streamlined. These will be the cost of refurbishment if we do nothing to change the supply chain and the way we currently do things. We anticipate that in the next stages of work on the project that through the process of optimization and innovation within the supply chain, we will be able to bring these costs down to mass-deployable levels.

Assumptions

In the absence of a "real" property we have made the following assumptions:

- No structural repairs required
- External finishes in need of uplift
- Doors and windows leaky and require upgrading
- Existing Loft and Cavity wall insulation, but not enough and improperly installed
- Existing sash windows, frame in good structural condition but is single glazed
- Suspended timber floor, existing old carpets
- Existing bay window
- Fireplaces not in use
- Boilers inefficient
- No renewables on roof
- No room in roof
- No mechanical ventilation or air conditioning
- Not in a conservation area
- Not newly redecorated, no new kitchens or bathrooms
- Resident in occupation

SCENARIO 1: "QUICK AND EASY" INSTALLATION

TARGETS	
Wall U-Value	0.15 - 0.20 W/m²K
Roof U-Value	0.12 - 0.25 W/m²K
Floor U-Value	No floor insulation
Window/Door U-Value	As spec - 12mm conservation double glazing
Airtightness	5 m³/h/m²@50 Pa

- Sweep, clear, fill with insulation and cap chimney
- Single room heat recovery in kitchens and bathrooms
- Install smart meters
- Install easy to use thermostat and controls
- Fit new energy-efficient boiler, insulated hot water tank and insulated pipes
- Top up existing loft insulation, fix ventilation, thermal bridging detail at eaves.
- 100mm external wall insulation, insulate window reveals, insulate ground level slab edge, insulate door recesses and soffit, improve airtightness around pipe penetrations
- Insulate cavity party wall
- Replace glazing with 12mm "conservation" double glazing, reform frame, new draught seals and improve airtightness of windows.
- Replace bay window glazing as above, external wall insulation as above, strip and insulate spandrel panels, remove pitched roof and renew with insulated flat roof

COSTS	
Materials and Labour	£20,370
Site Prelims	£1,750
Overheads	£1,220
Profit	£660
TOTAL	**£24,000**

SCENARIO 2: "QUICK AND EASY" INSTALLATION WITH MINOR INTERNAL WORKS

TARGETS	
Wall U-Value	0.15 - 0.20 W/m²K
Roof U-Value	0.12 - 0.25 W/m²K
Floor U-Value	No floor insulation
Window/Door U-Value	As spec - 12mm conservation double glazing
Airtightness	5 m³/h/m²@50 Pa

- Sweep, clear, fill with insulation and cap chimney
- Single room heat recovery in kitchens and bathrooms
- Install smart meters
- Install easy to use thermostat and controls
- Fit new energy-efficient boiler, insulated hot water tank and insulated pipes
- Top up existing loft insulation, fix ventilation, thermal bridging detail at eaves.
- 100mm external wall insulation, insulate window reveals, insulate ground level slab edge, insulate door recesses and soffit, improve airtightness around pipe penetrations
- Replace glazing with 12mm "conservation" double glazing, reform frame, new draught seals and improve airtightness of windows.
- Replace bay window glazing as above, external wall insulation as above, strip and insulate spandrel panels, remove pitched roof and renew with insulated flat roof
- *Remove existing floor finish, seal around skirting board, lay down plywood to seal gaps in floor, new floor finish on top, ensure ventilation is preserved*

COSTS	
Materials and Labour	£22,650
Site Prelims	£1,950
Overheads	£1,350
Profit	£740
TOTAL	**£26,690**

SCENARIO 3: "TOWARDS LOW CARBON INSTALLATION"

TARGETS	
Wall U-Value	0.15 - 0.20 W/m²K
Roof U-Value	0.12 - 0.25 W/m²K
Floor U-Value	No floor insulation
Window/Door U-Value	1.2 - 1.4 W/m²K
Airtightness	3 m³/h/m²@50 Pa
MVHR spec	SFP = 8 90% efficiency

- Sweep, clear, fill with insulation and cap chimney
- *Install MVHR, use existing chimney space for service runs*
- Install smart meters
- *Install intelligent building control system*
- Fit new energy-efficient boiler, insulated hot water tank and insulated pipes
- *Remove and replace existing loft insulation with better high performance material with good thermal detailing at eaves/top of wall junction, ventilate eaves*
- *Re-roof and install photovoltaic/solar thermal roof tiles, extend eaves to accommodate external wall insulation and larger gutters, extend verge to accommodate external wall insulation*
- *200mm external wall insulation, insulate window reveals, insulate ground level slab edge, improve airtightness around pipe penetrations*
- *New insulated external door and creation of draught lobby (enclose door recess, external door in line with facade), draughtproofing of doorway*
- *Remove existing windows and install new thermally-broken aluminium powder coated double glazed windows units, extend window cills*
- *Remove existing bay window, construct new bay window that is insulated, thermally broken and airtight with double-glazed units.*
- Remove existing floor finish, seal around skirting board, lay down plywood to seal gaps in floor, new floor finish on top, ensure ventilation is preserved
- *Remove rainwater goods, reinstall and extend pipes, enlarge gutters, ensure fixings are insulated*

COSTS	
Materials and Labour	£49,000
Site Prelims	£4200
Overheads	£2950
Profit	£1600
TOTAL	**£57,750**

SCENARIO 4: "TOWARDS LOW CARBON INSTALLATION WITH ROOM IN ROOF

TARGETS	
Wall U-Value	0.15 - 0.20 W/m²K
Roof U-Value	0.12 - 0.25 W/m²K
Floor U-Value	No floor insulation
Window/Door U-Value	1.2 - 1.4 W/m²K
Airtightness	3 m³/h/m²@50 Pa
MVHR spec	SFP = 8 90% efficiency

- Sweep, clear, fill with insulation and cap chimney
- Install MVHR, use existing chimney space for service runs
- Install smart meters
- Install intelligent building control system
- Fit new energy-efficient boiler, insulated hot water tank and insulated pipes
- *Loft conversion, insulate between and underneath rafters, ventilate eaves, internal finishes, new draughtproofed loft hatch, insulate around chimney internally, sealing around service penetrations and flues, good thermal detailing at eaves*
- *Re-roof and install photovoltaic/solar thermal roof tiles, extend eaves to accommodate external wall insulation and larger gutters, extend verge to accommodate external wall insulation*
- 200mm external wall insulation, insulate window reveals, insulate ground level slab edge, improve airtightness around pipe penetrations
- New insulated external door and creation of draught lobby (enclose door recess, external door in line with facade), draughtproofing of doorway
- Remove existing windows and install new thermally-broken aluminium powder coated double glazed windows units, extend window cills
- Remove existing bay window, construct new bay window that is insulated, thermally broken and airtight with double-glazed units.
- Remove rainwater goods, reinstall and extend pipes, enlarge gutters, ensure fixings are insulated
- Remove existing floor finish, seal around skirting board, lay down plywood to seal gaps in floor, new floor finish on top, ensure ventilation is preserved

COSTS	
Materials and Labour	£70,230
Site Prelims	£6,030
Overheads	£4,190
Profit	£2,290
TOTAL	**£82,740**

SCENARIO 5: "TOWARDS LOW CARBON INSTALLATION WITH NEW KITCHEN AND BATHROOM

TARGETS	
Wall U-Value	0.15 - 0.20 W/m^{2}K
Roof U-Value	0.12 - 0.25 W/m^{2}K
Floor U-Value	0.15 W/m^{2}K
Window/Door U-Value	1.2 - 1.4 W/m^{2}K
Airtightness	3 m^3/h/m^2@50 Pa
MVHR spec	SFP = 8 90% efficiency

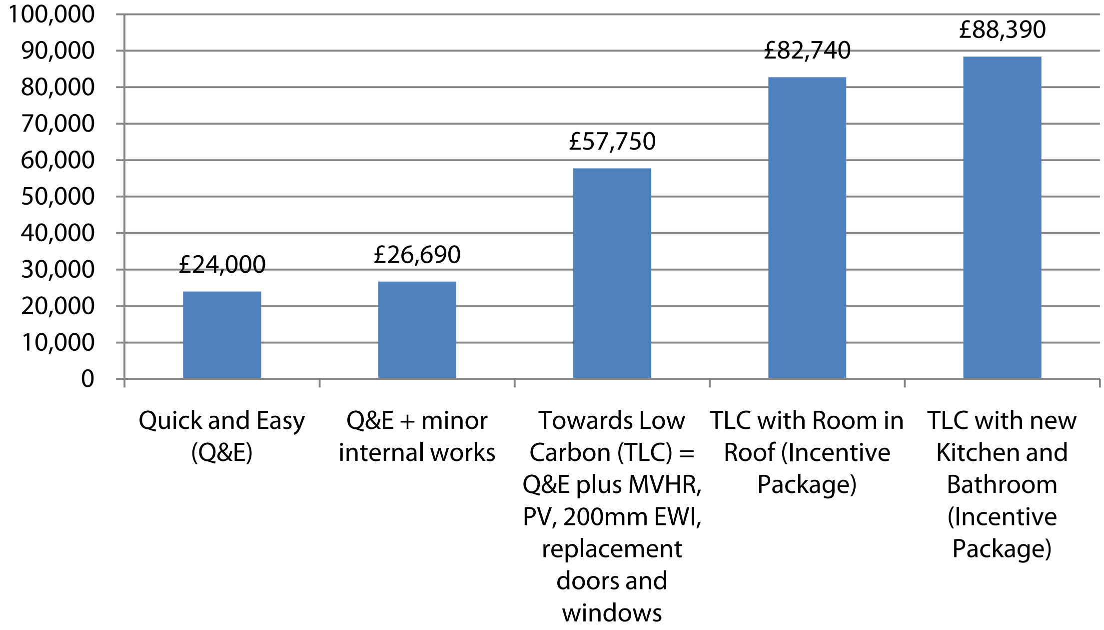
- Sweep, clear, fill with insulation and cap chimney
- Install MVHR, use existing chimney space for service runs
- Install smart meters
- Install intelligent building control system
- Fit new energy-efficient boiler, insulated hot water tank and insulated pipes
- Remove and replace existing loft insulation with better high performance material with good thermal detailing at eaves/top of wall junction, ventilate eaves
- Re-roof and install photovoltaic/solar thermal roof tiles, extend eaves to accommodate external wall insulation and larger gutters, extend verge to accommodate external wall insulation
- 150mm external wall insulation, insulate window reveals, insulate ground level slab edge, improve airtightness around pipe penetrations
- New insulated external door and creation of draught lobby (enclose door recess, external door in line with facade), draughtproofing of doorway
- Remove existing windows and install new thermally-broken aluminium powder coated double glazed windows units, extend window cills
- Remove existing bay window, construct new bay window that is insulated, thermally broken and airtight with double-glazed units.
- Remove rainwater goods, reinstall and extend pipes, enlarge gutters, ensure fixings are insulated
- *Lift floorboards, insulate between and under joists, ventilate under floor to avoid condensation, new floor finish*
- *New kitchen and bathroom*

COSTS	
Materials and Labour	£75,030
Site Prelims	£6,440
Overheads	£4,480
Profit	£2,440
TOTAL	**£88,390**

COMPARISON OF SCENARIOS

The following table summarises the costing exercise for all five scenarios. Using current costing methodology, the TLC scenario costs over twice as much as the Quick and Easy Scenario , and the addition of incentives in order to encourage the homeowners to go for the higher spec retrofit package would quadruple the cost.

Going for the Quick and Easy scenario is certainly the cheapest approach, but will it be enough to reach our targets? Going for Q&E means ensuring that the home is not performing badly, but for the house to perform well in terms of "low carbon" or "zero carbon" you have to go the next level up. The challenge now is to figure out how we can bring this cost down - can it be achieved by offsite manufacture and new technologies, or will optimising the supply chain to make it more efficient be enough?



Innovation Potential Ideas

The following consist of descriptions and sketch ideas for products that deal with tricky thermal junctions - either complete, easy-install assemblies that clip or slide into place, thermally broken fixings, or enabling products that make "mass bespoking" easier. These are just a few of the ideas - there are more in the "Innovation Potential" columns for each of the house types previously discussed. Some of these details may already exist but have not been brought into the mainstream, possibly due to the production volume, lack of marketing, lack of knowledge of the design industry, or lack of skilled installers.

COMBINED EAVES / VENTILATION BOARD

To insulate the sloping part of an eave, particularly a 'dropped eave' where the sloping part is longer, usually means either taking off the tiles to install rafter vent trays and insulation, sliding insulation between the rafters from the roof space with no vent tray, or removing the ceiling to fit insulation from the inside. A recent detail has suggested a vent tray that is slid in from the roof space and wedged in place with insulation.

The proposed board, possibly eps or phenolic, combines insulation and ventilation together so that only one unit has to be installed, either from the roof space or eaves level, without removing the tiles. The down sides might be:

- Making sure the insulation fits snugly between the rafters
- Cut-outs would be necessary where ceiling joists are side nailed into rafters.