



Programme Area: Buildings

Project: Building Supply Chain for Mass Refurbishment of Houses

Title: Technical solutions report

Abstract:

Please note this report was produced in 2011/2012 and its contents may be out of date. This deliverable is number 3a of 7 in Work Package 3. It identifies the key retrofit measures that should be implemented to maximise impact (loft insulation, cavity wall insulation, tank and pipe insulation, high efficiency boiler installation, draughtproofing and repair of doors and windows) together with an analysis of how retrofit measures should be bundled to maximise impact in terms of performance, cost effectiveness, waste reduction and minimisation of disruption. The findings of this report will be used as a basis for further deliverables in this Work Package.

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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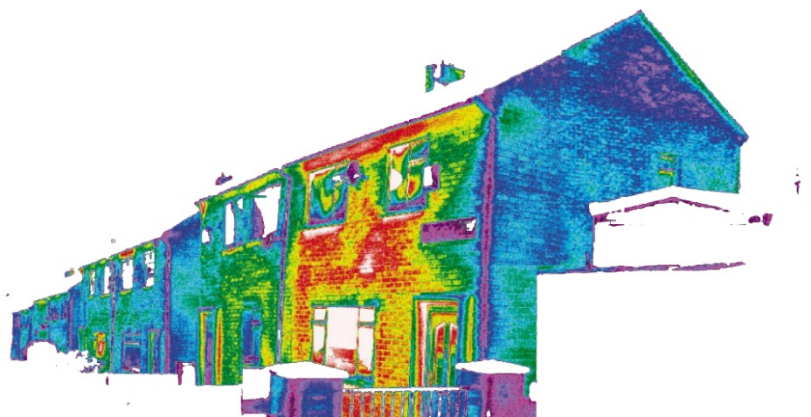
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The **ENERGY ZONE**
CONSORTIUM:



PEABODY



Optimising Thermal Efficiency of Existing Housing

Technical Solutions Report

Final Submission

Submitted by  on behalf of the
ENERGY ZONE CONSORTIUM

17 June 2011

Optimising Thermal Efficiency of Existing Housing

Technical Solutions Report

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Issue

Final issue

Action

- Accepted
- Accepted subject to minor changes
- Major re-issue required

Signature

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EXECUTIVE SUMMARY

This report relates to the ETI Optimising Thermal Efficiency in Existing Housing Project deliverable 3.3a, a "Technical Solutions Matrix" which will form the basis for recommendations on whole house solutions for the various house types.

WORK PACKAGE OBJECTIVES

- To undertake a comprehensive sweep of what is currently available as well as emerging developments
- Solutions will be performance rather than product-based and will cover categories that relate to thermal efficiency - including insulation, roof solutions, wall build-ups and components, flooring materials and build-ups, windows, doors, frames, glazing, coatings and joints.
- The technical solutions should be clearly evaluated and weighted according to an established set of criteria that fall under the following areas: design, construction, supply chain, customer acceptance and cost

METHODOLOGY

In order to arrive at a simple technical solutions matrix, we followed a thought process that took us through the problems and issues with existing housing that from a stakeholder point of view, could catalyse the retrofit process, to a component-based approach to identifying technical retrofit solutions and their associated risks in order to generate a list of solutions that would then make their way into the final matrix.

This non-house type specific approach is a slight variation from the original intent of the deliverable, but we thought this modular approach would enable us to create a toolset for evaluating technical solutions that may prove to be more valuable than the original deliverable itself, as the various components can then be adapted to investigate a wide range of house types.

KEY FINDINGS - EVALUATION MATRICES

The final Evaluation Matrix shows that the "Top 5" interventions are the ones that are already 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. Of interest are the thermal interventions that follow - improvement of building control systems, smart meters, airtightness, internal wall insulation and external wall insulation complete the "Top 10".

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.

It is worth noting that these synergies are two-way - for example if the Top 10 item is the primary intervention it would be worth considering accelerating the programme for the synergetic interventions so that they are done within the same retrofit exercise. However, of course if the synergetic intervention is one that is not likely to ever be implemented on the property then it should not be considered. If you look at it the other way around, if the homeowner is planning to install a new kitchen or bathroom in the near future then it is a perfect opportunity to pitch the argument for internal wall insulation.

NEXT STEPS

These results will serve as a helpful decision tool for the rest of the project, not just the whole house and virtual refurb exercises. Because the factors have been laid out in a transparent and systematic manner, future-state supply chain, customer engagement, policy, and design process can be tweaked based on the gaps identified in the Evaluation and Synergy Matrices.

BACKGROUND

This report relates to the ETI Optimising Thermal Efficiency in Existing Housing Project deliverable 3.3a, a "Technical Solutions Matrix" which will form the basis for recommendations on whole house solutions for the various house types.

This matrix will consist of an infographic that will investigate the various solutions that can be used to improve thermal efficiency in our existing housing stock. It will set each solution out against a range of criteria related to design, construction, supply chain, customer acceptance and policy. The original intent was relate these criteria to the range of house types that will be covered in the study, but as the stock segmentation is still in its early stages we have modified the deliverable slightly to come up with a more modular approach to analysing the technical solutions.

WORK PACKAGE OBJECTIVES

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This non-house type specific approach is a slight variation from the original intent of the deliverable, but we thought this modular approach would enable us to create a toolset for evaluating technical solutions that may prove to be more valuable than the original deliverable itself, as the various components can then be adapted to investigate a wide range of house types. This is in keeping with the original concept of the deliverable as being a clear and transparent decision-making tool for the next stage of work which is the Whole House Solutions.

Why should I retrofit?

The following graphic represents the problems and issues that plague our existing housing stock today - not all of them are thermal efficiency related of course, and in fact perhaps the most motivated improvements are the ones that people would go for, such as new kitchens and bathrooms or redecoration.

While in this project we would mainly focus on the thermal improvements, it would be worth keeping in mind all the other added value non-thermal improvements, as these may prove to be the most important key motivators and incentives that will encourage stakeholders to undertake retrofit.

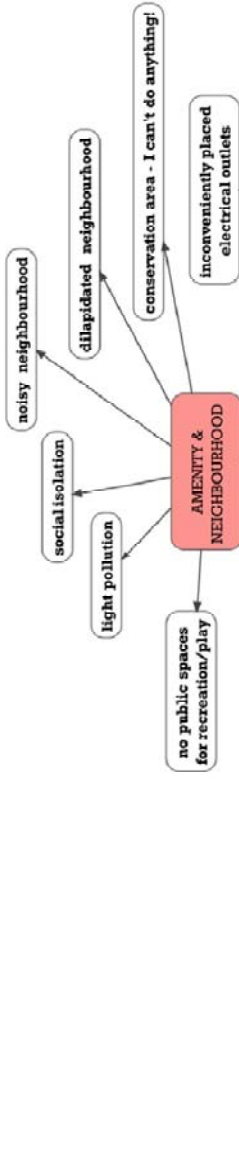
The diagram is divided into the following categories:

1. **Comfort, Energy and Water Efficiency** - issues under this category relate to factors that influence energy efficiency, water management, thermal comfort and carbon emissions. These are the issues that are the most relevant to the OTEoEH project.
2. **Functionality** - issues under this category relate to the functional use of the spaces in the house and can typically be remedied by a combination of lifestyle analysis and spatial rearrangement. These solutions could be added value opportunities that may enhance the retrofit offering.
3. **Amenity and Neighbourhood** - issues under this category relate to the wider context of the property, and can be interesting things to look into in terms of neighbourhood scale enhancements, which can be ideal added-value opportunities when dealing with street-by-street or community retrofit programmes.
4. **Lifestyle and Space** - issues under this category relate to changing circumstances or occupancies where the existing space is no longer enough to meet storage or activity needs. These could indicate incentives for added storage space, the creation of extensions or internal layout reconfiguration.
5. **Maintenance and Repair** - issues under this category are mainly to do with general dilapidation of the property, and are issues that would probably need to be dealt with when any major retrofit work is undertaken, even if they are not thermally related. If these issues are not dealt with at the point of retrofit, any measures taken by the owner or occupier to undertake these repairs at a later date may compromise the quality or performance of the installed retrofit solutions.
6. **Health and Safety** - issues under this category are a more extreme degree of dilapidation that goes beyond the aesthetic and may actually impact on the health and safety of the occupants. Ethically one can argue that if these issues are encountered in a home then they should be addressed, but this poses a cost escalation and construction delay risk if these are not identified at survey stage.
7. **Decoration and Aesthetics** - issues under this category refer to items that are perhaps functional but not aesthetically pleasing and would therefore be an added-value incentive

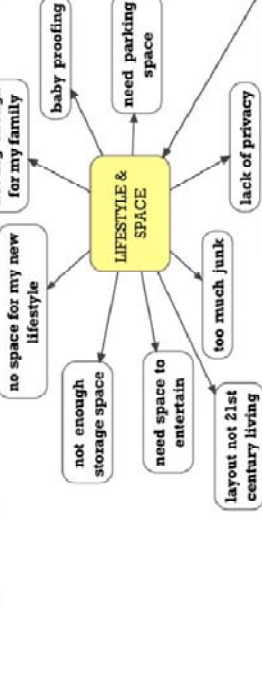
for the owners and occupants to beautify their homes during the course of the thermal retrofits.

These issues can be taken either one of two ways - they can be the primary driver for retrofit, with the thermal aspects tacked on as an added-value cost-effective solution, or vice versa.

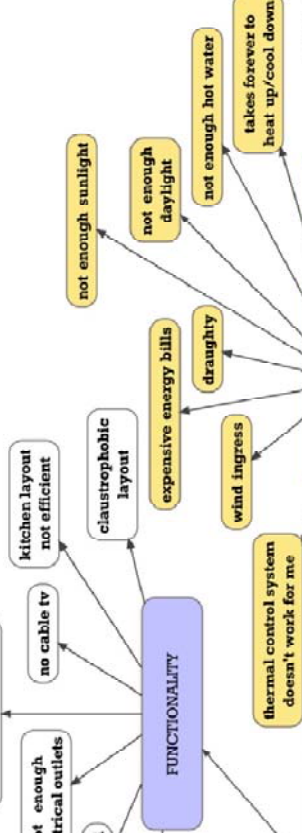
Neighbourhood scale opportunities



Lifestyle Incentives

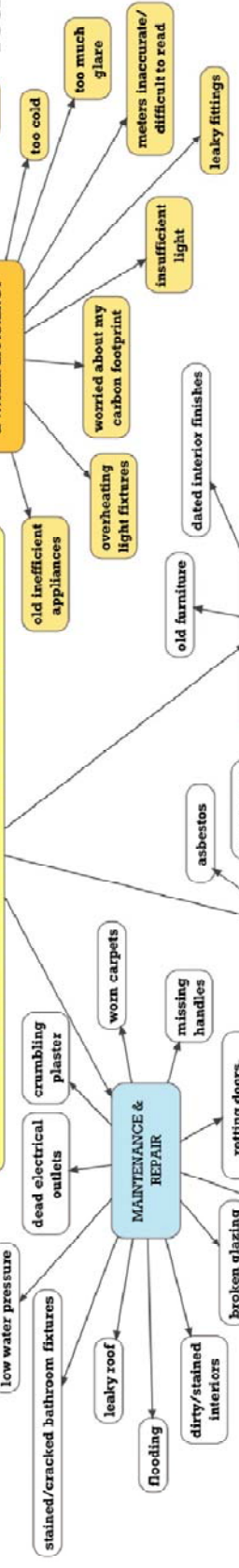


Added value opportunities

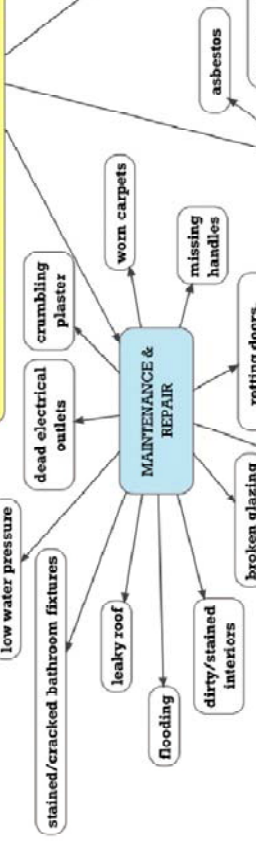


WHAT'S WRONG WITH MY HOME?

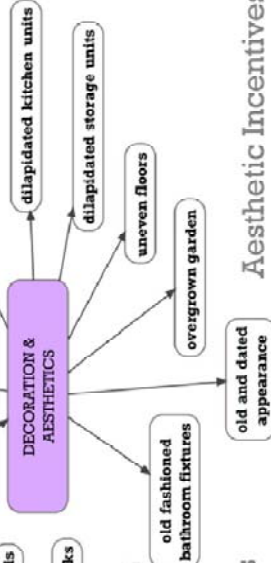
ETI OTEoEH
Technical Solutions



General repairs



Essential improvements



Aesthetic Incentives



How should I retrofit: Generating the Technical Solutions

The following diagram illustrates the approach to generating the list of likely technical solutions.

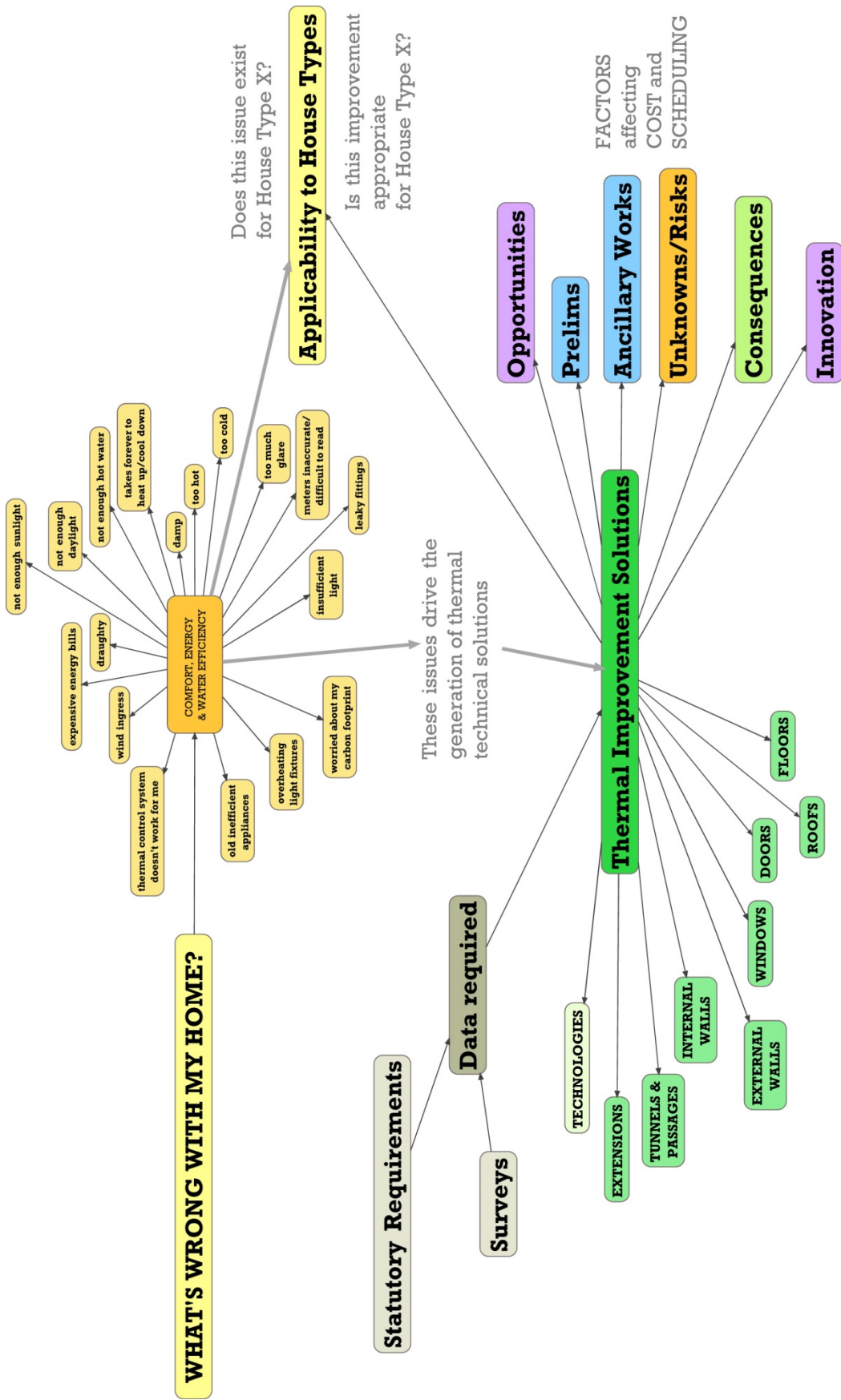
Initially we looked at two crucial aspects that will greatly influence the success of any retrofit solution - **Statutory Requirements**, which inform what is and what isn't possible, and **Surveys or Data Required**, which is a critical component that needs to be carried out properly to ensure that the project is delivered on time, with high levels of quality and at with a reliable costing mechanism.

Using the "Comfort, Energy & Water Efficiency" section of the "What's Wrong with my Home?" diagram as the starting point, we then looked at thermal improvement solutions using a component based approach, namely: Floors, Roofs, Doors, Windows, External and Internal Walls, Tunnels and Passages, and Extensions. We also touched briefly on Technologies as these would likely be a part of the whole house solutions even if they are beyond the current scope of the project.

Each of these component sections is then broken down into the following aspects:

1. **Data Required** specifically for that component, in order that the solution is designed and installed properly, and to a lesser degree of risk
2. **Typologies/Variations** within each component
3. The **Solutions** themselves
4. **Opportunities** for undertaking related work in a cost-and-resource-efficient manner
5. **Ancillary Works** which need to be carried out in order for the thermal improvement to be installed properly
6. **Unknowns and Risks** which could affect the delivery and cost of the project
7. Unintended **Consequences** which may arise as a result of carrying out the work
8. **Innovation** opportunities in terms of new products or processes that would assist in improving the retrofit process or in solving particular conditions or issues.

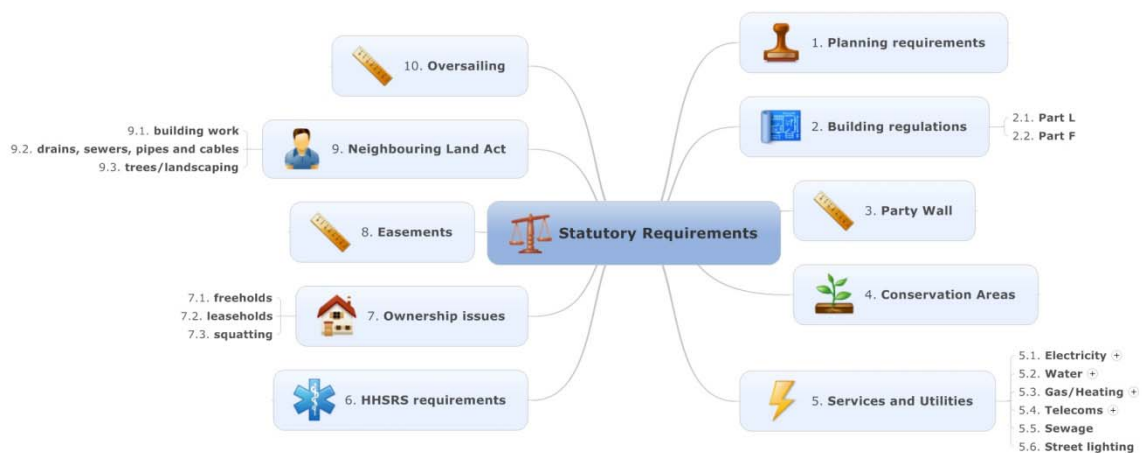
Prelims, or standard procedures and facilities that need to be set up or delivered in order for work to commence, is assumed to apply to all of the components and has therefore been considered in a separate section.



Statutory Requirements

One of the first things to consider before undertaking a retrofit project is to determine what statutory requirements apply to the property and to the project.

Some of these requirements consist of guidelines and restrictions, and some are monetary requirements that require the owner to pay for permits to carry out the work.

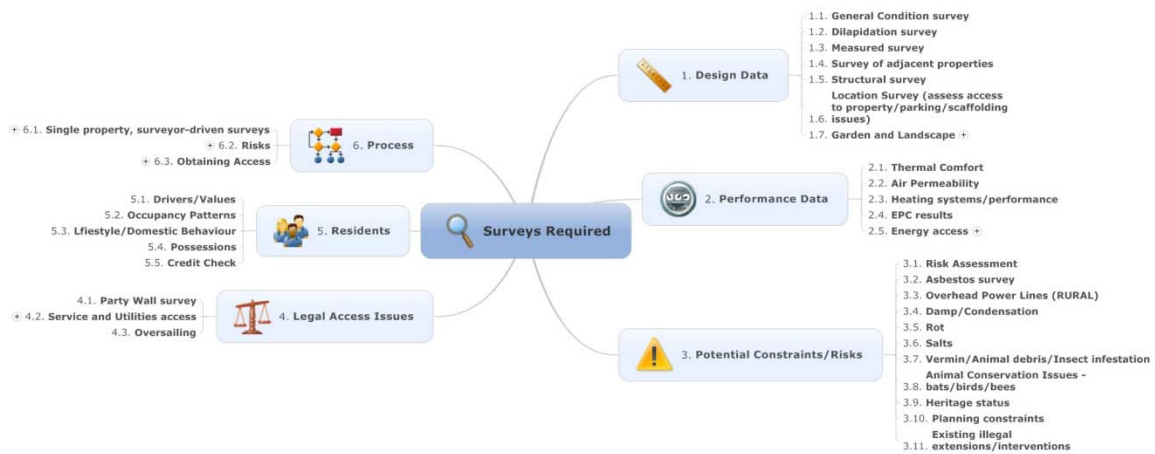


Some of the statutory requirements that need to be considered include:

	1. Planning requirements
	2. Building regulations
2.1.	Part L
2.2.	Part F
	3. Party Wall
	4. Conservation Areas
	5. Services and Utilities
5.1.	Electricity
	<ul style="list-style-type: none">• power lines• meters
5.2.	Water
	<ul style="list-style-type: none">• mains pipes• meters
5.3.	Gas/Heating
	<ul style="list-style-type: none">• lines• meters
5.4.	Telecoms
	<ul style="list-style-type: none">• cable TV• Internet cabling• satellite dishes• telephone lines• cellphone masts
5.5.	Sewage
5.6.	Street lighting
	6. HHSRS requirements
	7. Ownership issues
7.1.	freeholds
7.2.	leaseholds
7.3.	squatting
	8. Easements
	9. Neighbouring Land Act
9.1.	building work
9.2.	drains, sewers, pipes and cables
9.3.	trees/landscaping
	10. Oversailing

Surveys Required

One of the emerging critical issues for the retrofit process is the initial set of surveys that will inform how the retrofit programme for a particular property or neighbourhood will proceed. There is a long list of issues that need to be surveyed to be able to gain an accurate picture of what exists on the property as well as the risks involved. The general consensus is that the greater the amount of data, the lesser the risk associated with escalation of costs and delays in the scheduling.



The following table is a summary of the key items that would be required for a comprehensive pre-retrofit survey:

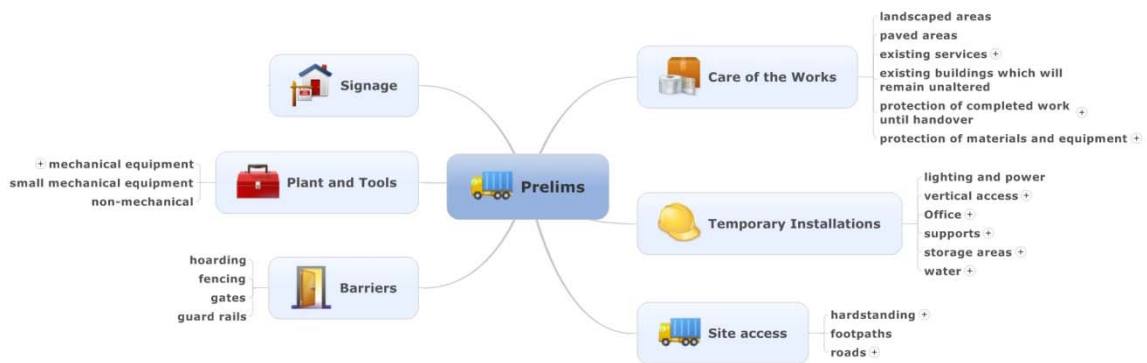
11. Design Data
11.1. General Condition survey
11.2. Dilapidation survey
11.3. Measured survey
11.4. Survey of adjacent properties
11.5. Structural survey
11.6. Location Survey (assess access to property/parking/scaffolding issues)
11.7. Garden and Landscape
<ul style="list-style-type: none"> • Tree survey • Tree preservation • Habitats
12. Performance Data
12.1. Thermal Comfort
12.2. Air Permeability
12.3. Heating systems/performance
12.4. EPC results
12.5. Energy access
<ul style="list-style-type: none"> • Community energy connections • On-site renewables
13. Potential Constraints/Risks
13.1. Risk Assessment
13.2. Asbestos survey
13.3. Overhead Power Lines (RURAL)
13.4. Damp/Condensation
13.5. Rot
13.6. Salts
13.7. Vermin/Animal debris/Insect infestation
13.8. Animal Conservation Issues - bats/birds/bees
13.9. Heritage status
13.10. Planning constraints
13.11. Existing illegal extensions/interventions

14. Legal Access Issues
14.1. Party Wall survey
14.2. Service and Utilities access
<ul style="list-style-type: none"> • Cable TV boxes • Electricity • Gas • Telecoms • Water • Sewage
14.3. Oversailing
15. Residents
15.1. Drivers/Values
15.2. Occupancy Patterns
15.3. Lifestyle/Domestic Behaviour
15.4. Possessions
15.5. Credit Check
16. Process
16.1. Single property, surveyor-driven surveys
<ul style="list-style-type: none"> • Develop options for aerial, desktop, laser, lidar or large-scale GIS survey methods • Pre-survey (Develop pre-survey questionnaire for occupiers to fill out, similar to Germany; High-level pre-survey required to determine which surveys need to be done)
16.2. Risks
<ul style="list-style-type: none"> • Cost of survey • Surveyor fatigue - diminishing quality for multiple properties done in the same day
16.3. Obtaining Access
<ul style="list-style-type: none"> • Opportunity for utilities and services consultant to negotiate with all the necessary service providers

Prelims

Prelims consist of anything that need to be set up on the site prior to the work being done, to ensure a comfortable working environment for the workers and provide an environment that works in terms of access, delivery and storage of materials and the protection of existing areas and features that will remain untouched by the retrofit activities.

Simultaneous or closely-programmed improvements, and ideally the installation of interventions on several properties or even an entire street or neighbourhood, allow economies of scale to be achieved since the cost of putting these facilities in place can be shared and more efficiently utilised.



The following table is a summary of the key items involved in preliminary works.

17. Care of the Works

- 17.1. landscaped areas
- 17.2. paved areas
- 17.3. existing services
 - protection
 - temporary arrangements
- 17.4. existing buildings which will remain unaltered
- 17.5. protection of completed work until handover
 - fire
 - weather protection
 - security
- 17.6. protection of materials and equipment
 - security
 - fire
 - weather protection

18. Temporary Installations

- 18.1. lighting and power
- 18.2. vertical access
 - scaffolding
 - gantries
 - ladders
 - mobile towers
 - platforms
 - weather enclosures
- 18.3. Office
 - shelving and storage
 - draughtsman's table
 - lockable fire-resistant file cabinet
 - security
 - comfort - heating, ventilation, sanitary facilities
 - telecommunications
- 18.4. supports
 - shores
 - props
 - struts
- 18.5. storage areas
 - resident possessions
 - construction materials
- 18.6. water
 - drinking
 - cleaning
 - disposal

19. Site access

19.1. hardstanding

- vehicle parking
- storage

19.2. footpaths

19.3. roads

- tracks
- crossings
- ramps

20. Barriers

20.1. hoarding

20.2. fencing

20.3. gates

20.4. guard rails

21. Plant and Tools

21.1. mechanical equipment

- hosting
- earthwork
- general
- transport

21.2. small mechanical equipment

21.3. non-mechanical

22. Signage

Floors



The following table is a summary of the key issues and tasks involved in retrofit solutions for floors:

23. Data required

- 23.1. Floor construction
- 23.2. Structural integrity
- 23.3. Ventilation regime
- 23.4. Underfloor electrical wiring and pipework routes
- 23.5. performance specifications for materials

24. Typologies

- 24.1. Level
 - Ground (raised, on-ground)
 - Upper
 - Basement (Warm cellar, Cold cellar, Earth cellar, Vented void, Part basement)
- 24.2. Construction
 - Framed
 - Solid

25. Solutions

- 25.1. Insulation
 - within depth
 - below
 - above
 - pipework
- 25.2. Improve airtightness
 - hardboard under floor finish
 - sealed first floor to prevent heat loss and draughts
- 25.3. Replace floor (if severely dilapidated)
 - New concrete floor
 - New timber framed floor
 - New metal framed floor
- 25.4. Ventilation
 - ground floor
 - upper floor
- 25.5. Damp proofing
- 25.6. Draughtproofing
 - doors
 - pipework to outside
 - suspended floorboards

26. Ancillary Works

- 26.1. Removal/storage of furniture and possessions
- 26.2. Floor Finishes
 - tasks (Removal, Recovery, Reinstallation/ Installation, Adaptation/re-cutting)
 - types (carpet, laminate, tile, stone, wood)
- 26.3. Clean out void
- 26.4. Electrical
 - tie up ground floor power cables
 - set up temporary lighting
- 26.5. Sewage
- 26.6. support waste pipes
- 26.7. Pest control
- 26.8. Defect treatments
 - DPC failure (physical replacement, chemical DPC, electro-osmotic DPC, clay pot/clay tube)
 - Subsidence
 - Structural defects
 - Floor defects

27. Opportunities

- 27.1. installation of underfloor heating

28. Unknowns/Risks

- 28.1. Asbestos
- 28.2. Electrical Wiring
 - existing substandard installations
 - existing hazardous installations (e.g. electrics under bath)
 - non-compliance with regs
- 28.3. Ducts, flues and pipework
- 28.4. Sound floor level
- 28.5. Party wall
 - footings
 - continuous floors
- 28.6. future work might affect performance of current retrofit work
- 28.7. Ventilation
- 28.8. Damp and water ingress
- 28.9. Rot
- 28.10. Dust
- 28.11. Vermin/insect infestations

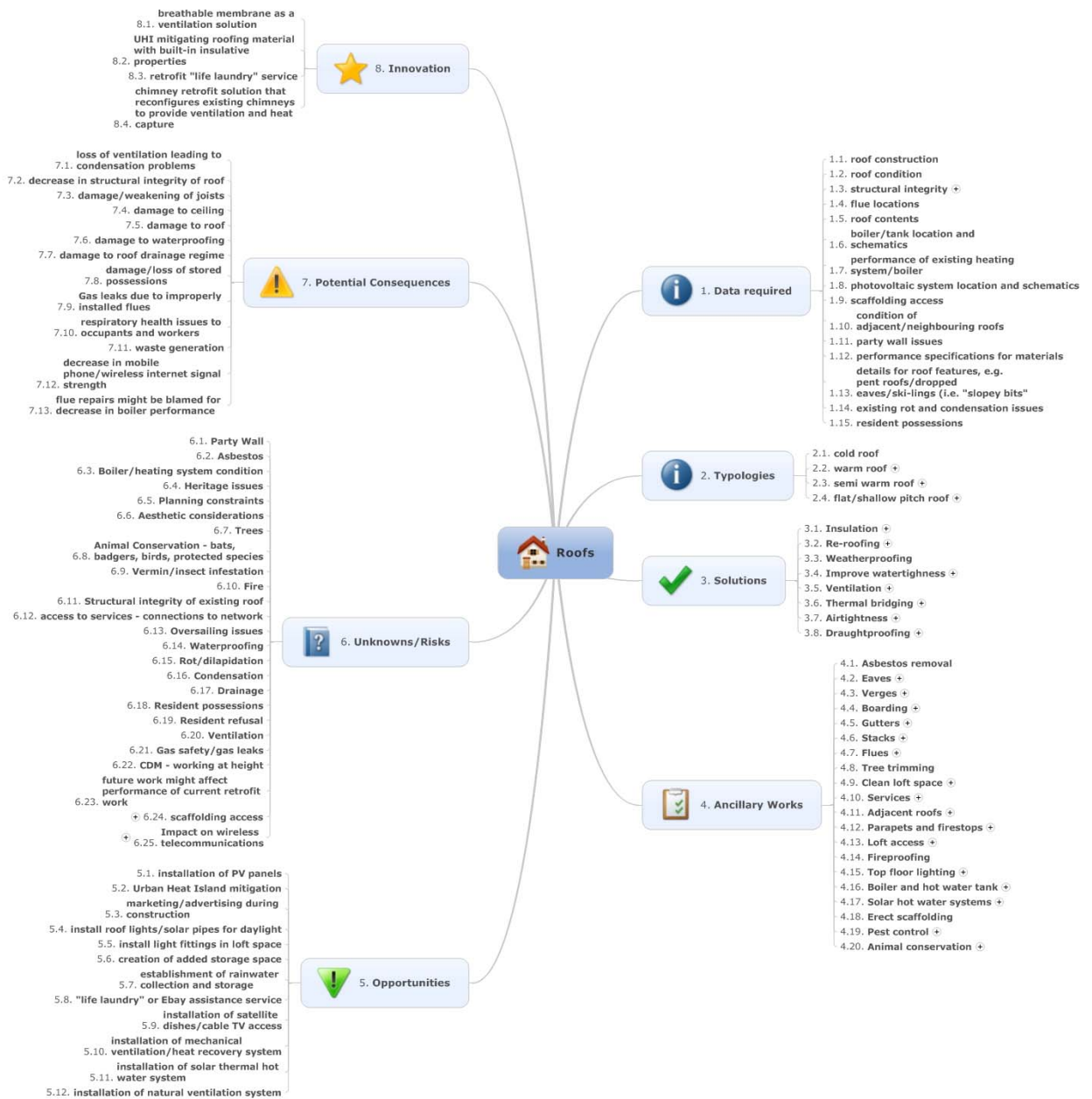
29. Potential Consequences

- 29.1. Most disruption to residents
- 29.2. Disruption of ventilation features
- 29.3. Compromise existing waterproofing
- 29.4. Impact of level changes
 - Doors
 - Stairs
 - Built-in furniture (kitchens, bathrooms)
 - Floor-mounted fixtures and fittings (kitchens, bathrooms)
- 29.5. Damage to wiring/pipework
- 29.6. Damage to interior decorations
- 29.7. waste generation

30. Innovation

- 30.1. thin insulated carpets/laminate flooring products

Roofs



The following table is a summary of the key issues and tasks involved in retrofit solutions for roofs:

31. Data required	
31.1.	roof construction
31.2.	roof condition
31.3.	structural integrity
	<ul style="list-style-type: none"> • current configuration • ability to support new roofing material • ability to support PV/solar thermal
31.4.	flue locations
31.5.	roof contents
31.6.	boiler/tank location and schematics
31.7.	performance of existing heating system/boiler
31.8.	photovoltaic system location and schematics
31.9.	scaffolding access
31.10.	condition of adjacent/neighbouring roofs
31.11.	party wall issues
31.12.	performance specifications for materials
31.13.	details for roof features, e.g. pent roofs/dropped eaves/ski-lings (i.e. "slopy bits")
31.14.	existing rot and condensation issues
31.15.	resident possessions
32. Typologies	
32.1.	cold roof
32.2.	warm roof
	<ul style="list-style-type: none"> • with dormer windows • without dormer windows
32.3.	semi warm roof
	<ul style="list-style-type: none"> • with rooflights • without rooflights
32.4.	flat/shallow pitch roof
	<ul style="list-style-type: none"> • flat cold • flat warm

33. Solutions	
33.1.	Insulation
	<ul style="list-style-type: none"> • ceiling • pitched roof (between rafters, above rafters, below rafters) • flat roof (ceiling, inverted roof, within roof, above ceiling void) • wall and roof • gable ends • flues (stacks, chimneys) • dormer cheeks • roof features (pent roofs, dropped eaves, ski-lings) • hot water tank • boiler • pipework
33.2.	Re-roofing
	<ul style="list-style-type: none"> • timber frame • steel frame • thatched roof
33.3.	Weatherproofing
33.4.	Improve watertightness
	<ul style="list-style-type: none"> • seals
33.5.	Ventilation
	<ul style="list-style-type: none"> • breathable membrane • renew ventilation features at eaves • create ventilation features at eaves • renew ventilation features at ridge • create ventilation features at ridge
33.6.	Thermal bridging
	<ul style="list-style-type: none"> • EWI and ceiling insulation • EWI and roof insulation • Eaves detail
33.7.	Airtightness
	<ul style="list-style-type: none"> • roof • flues - chimneys (sealing, removal, thermal pillow), stacks
33.8.	Draughtproofing
	<ul style="list-style-type: none"> • loft hatch

34. Ancillary Works

34.1. Asbestos removal

34.2. Eaves

- extension
- capping

34.3. Verges

- extension
- capping

34.4. Boarding

- installation
- replacement
- repair

34.5. Gutters

- clean
- repair
- remove
- replace
- renew

34.6. Stacks

- Remove
- Extend
- Replace
- Renew
- Swan neck adjustments
- Drain connection adjustments
- Connection adjustments, e.g. sink
- Final fixing
- Install hoppers
- Types (soil stacks, vent stacks)

34.7. Flues

- Remove
- Extend (boiler flue, gas fire flue, discharge pipe from boiler, condensing pipework, extractor fan pipework)
- Replace
- Renew
- Connection adjustments
- Final fixing
- Install hoppers
- Types (boiler, generator, gas fire, extractor fan)

34.8. Tree trimming

34.9. Clean loft space

- possessions (removal, storage, reinstatement)
- animal debris
- vermin/pest removal

- protected species relocation (bats, birds, bees)

34.10. Services

- Electrical rewiring
- Telephone/Internet lines
- Aerials/satellite dishes (removal/disconnection, temporary provisions, reinstallation)

34.11. Adjacent roofs

- jointing

34.12. Parapets and firestops

- protection
- repair
- renew
- construct

34.13. Loft access

- (for conversions) loft hatch creation
- access ladder
- access deck to HW tank

34.14. Fireproofing

34.15. Top floor lighting

- recessed downlights (protection, removal and storage, reinstallation, replacement)
- other lighting (protection, removal and storage, reinstallation, replacement)

34.16. Boiler and hot water tank

- protection
- removal and storage
- reinstallation
- upgrade/replacement

34.17. Solar hot water systems

- protection
- removal and storage
- new installation
- optimisation

34.18. Erect scaffolding

34.19. Pest control

- removal of wasp nests
- pest extermination
- animal waste removal

34.20. Animal conservation

- bee relocation
- bats
- birds

35. Opportunities

- 35.1. installation of PV panels
- 35.2. Urban Heat Island mitigation
- 35.3. marketing/advertising during construction
- 35.4. install roof lights/solar pipes for daylight
- 35.5. install light fittings in loft space
- 35.6. creation of added storage space
- 35.7. establishment of rainwater collection and storage
- 35.8. "life laundry" or Ebay assistance service
- 35.9. installation of satellite dishes/cable TV access
- 35.10. installation of mechanical ventilation/heat recovery system
- 35.11. installation of solar thermal hot water system
- 35.12. installation of natural ventilation system

36. Unknowns/Risks

- 36.1. Party Wall
- 36.2. Asbestos
- 36.3. Boiler/heating system condition
- 36.4. Heritage issues
- 36.5. Planning constraints
- 36.6. Aesthetic considerations
- 36.7. Trees
- 36.8. Animal Conservation - bats, badgers, birds, protected species
- 36.9. Vermin/insect infestation
- 36.10. Fire
- 36.11. Structural integrity of existing roof
- 36.12. access to services - connections to network
- 36.13. Oversailing issues
- 36.14. Waterproofing
- 36.15. Rot/dilapidation
- 36.16. Condensation
- 36.17. Drainage
- 36.18. Resident possessions
- 36.19. Resident refusal

36.20. Ventilation

- 36.21. Gas safety/gas leaks
- 36.22. CDM - working at height
- 36.23. future work might affect performance of current retrofit work
- 36.24. scaffolding access

- over highways
- neighbouring properties
- cantilevered

36.25. Impact on wireless telecommunications

- internet wireless
- mobile phone signals

37. Potential Consequences

- 37.1. loss of ventilation leading to condensation problems
- 37.2. decrease in structural integrity of roof
- 37.3. damage/weakening of joists
- 37.4. damage to ceiling
- 37.5. damage to roof
- 37.6. damage to waterproofing
- 37.7. damage to roof drainage regime
- 37.8. damage/loss of stored possessions
- 37.9. Gas leaks due to improperly installed flues
- 37.10. respiratory health issues to occupants and workers
- 37.11. waste generation
- 37.12. decrease in mobile phone/wireless internet signal strength
- 37.13. flue repairs might be blamed for decrease in boiler performance

38. Innovation

- 38.1. breathable membrane as a ventilation solution
- 38.2. UHI mitigating roofing material with built-in insulative properties
- 38.3. retrofit "life laundry" service
- 38.4. chimney retrofit solution that reconfigures existing chimneys to provide ventilation and heat capture

Doors



The following table is a summary of the key issues and tasks involved in retrofit solutions for doors:

39. Data required	
39.1.	door inventory
39.2.	existing airtightness
39.3.	performance specifications for materials
40. Typologies	
40.1.	Front door
	<ul style="list-style-type: none"> • Flush with main wall
40.2.	Patio doors
40.3.	Back and side doors
40.4.	Garage doors
40.5.	Conservatory doors
41. Solutions	
41.1.	Replace doors
	<ul style="list-style-type: none"> • Take out (Remove /Recycle/Dispose of existing door and door frame) • Install energy efficient doors
41.2.	Make good
	<ul style="list-style-type: none"> • Re-glaze, upgrade single-glazed door lites • Repair door • Re-align
41.3.	Draughtproofing
41.4.	Thermal bridging
41.5.	Install new second door
	<ul style="list-style-type: none"> • creation of a new lobby • creation of a new porch

42. Ancillary Works	
42.1.	Decorative elements
	<ul style="list-style-type: none"> • Protect decorative elements • Restore/repair canopies • restore/repair lintels • restore/repair corbels
42.2.	Letterboxes
	<ul style="list-style-type: none"> • Recover and re-install • upgrade
42.3.	Doorbells and peepholes
	<ul style="list-style-type: none"> • Recover and re-install • upgrade
42.4.	Cat flaps
42.5.	Doorsteps
42.6.	Names and numbers
	<ul style="list-style-type: none"> • recover and re-install • upgrade
42.7.	Intercoms and security features
	<ul style="list-style-type: none"> • recover and re-install • upgrade
43. Opportunities	
43.1.	Reposition doors for better space layouts
43.2.	Replace letterboxes for better functionality/security/larger capacity
43.3.	Improvement of security rating
43.4.	Install security systems
43.5.	Develop door panel that can add insulation and draughtproofing that can be installed over existing door
44. Unknowns/Risks	
44.1.	Heritage issues
44.2.	Aesthetic choices
44.3.	future work might affect performance of current retrofit work

45. Potential Consequences

- 45.1. Temporary loss of security during installation
- 45.2. Creation of draughts/thermal bridging issues if not done concurrently with EWI

45.3. Loss of character

45.4. Water ingress/draught creation

46. Innovation

46.1. Doors with thermally efficient lites

46.2. Doors with integrated security systems

Windows

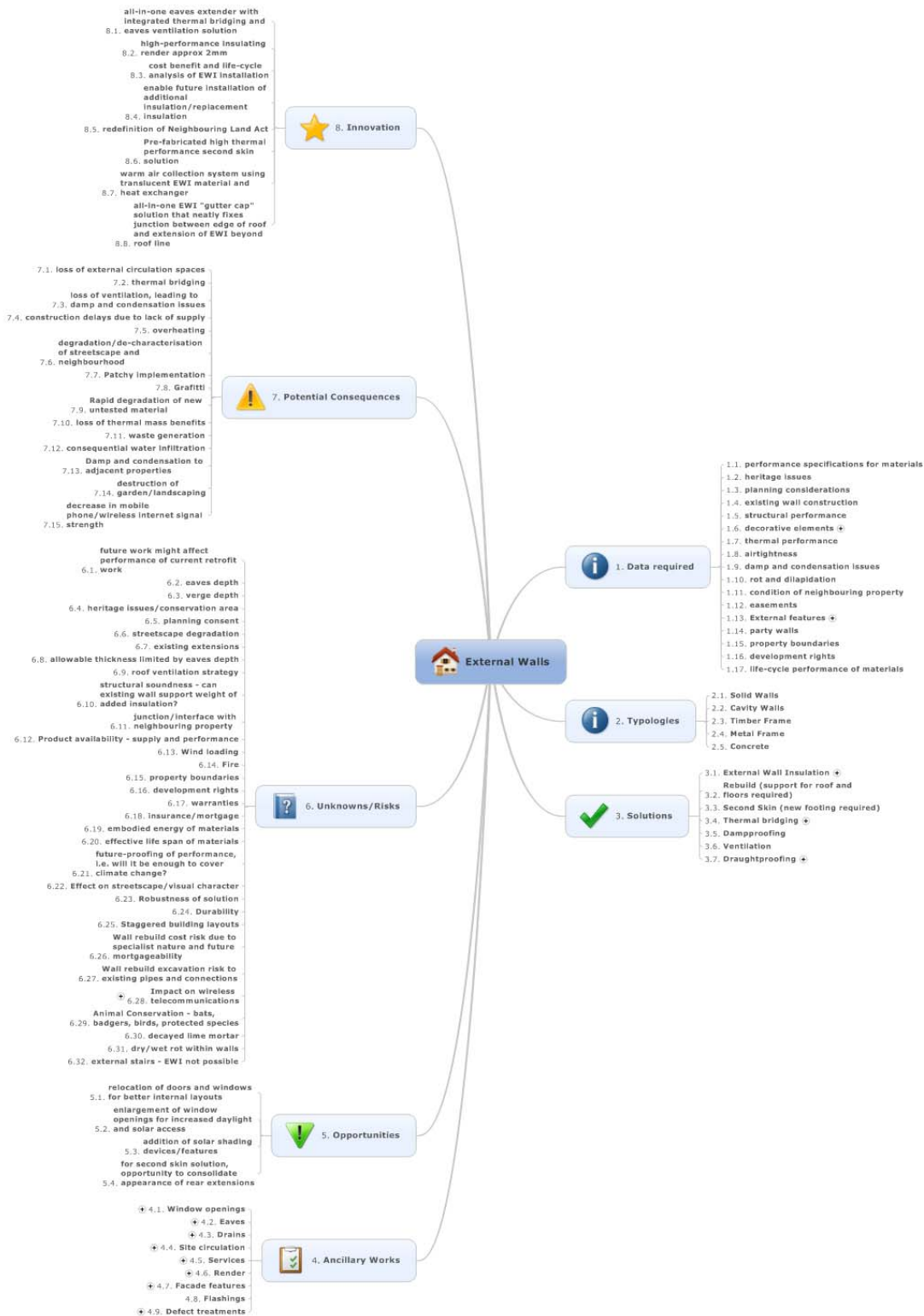


The following table is a summary of the key issues and tasks involved in retrofit solutions for windows:

47. Data required
47.1. performance specifications for materials
47.2. wall construction
47.3. airtightness
47.4. thermal performance
47.5. structural integrity of lintels
48. Typologies
48.1. flush to wall
<ul style="list-style-type: none"> • sash • tilt • hinged • tilt and turn
48.2. with window seat
48.3. projecting windows
<ul style="list-style-type: none"> • bay/bow/box • oriel
49. Solutions
49.1. Replace
<ul style="list-style-type: none"> • new sealing • replace fan lite with double glazing • new window and frame • double glazing • trickle vents • triple glazing • vacuum glazing • heat loss + solar gain coatings
49.2. Upgrade
<ul style="list-style-type: none"> • re-glaze • re-seal
49.3. Certification
<ul style="list-style-type: none"> • FENSA-approval
49.4. thermal bridging
<ul style="list-style-type: none"> • reposition in reveal to coincide with insulation zone • frame to reveal/wall
49.5. Insulation
<ul style="list-style-type: none"> • bay/bow/box walls

50. Ancillary Works
50.1. repair
<ul style="list-style-type: none"> • frame • lintels
51. Opportunities
51.1. future-proofing window openings to enable clip-in solutions to be installed in the future
51.2. reposition windows to improve internal layouts
51.3. enlarge window openings to improve daylight
51.4. creation of a useful window seat
51.5. conversion of bay windows to regular windows and vice-versa
52. Unknowns/Risks
52.1. future work might affect performance of current retrofit work
52.2. heritage issues
52.3. planning constraints
52.4. loadbearing windows that act as lintels
52.5. lintel repair - health and safety risks, cost risk
52.6. embodied carbon of windows
53. Potential Consequences
53.1. damage to external wall features
53.2. damage to internal wall features
53.3. condensation/damp moves from window to wall
53.4. degradation of aesthetic value
53.5. compromised home security
54. Innovation
54.1. future proofed window openings to accommodate clip-in solutions for future window replacement
54.2. clip-in window replacement solutions that can be completed in a few hours
54.3. double or triple glazed sash windows that can be used for conservation area

External Walls



The following table is a summary of the key issues and tasks involved in retrofit solutions for external walls:

55. Data required	
55.1.	performance specifications for materials
55.2.	heritage issues
55.3.	planning considerations
55.4.	existing wall construction
55.5.	structural performance
55.6.	decorative elements
	<ul style="list-style-type: none"> • details • suppliers
55.7.	thermal performance
55.8.	airtightness
55.9.	damp and condensation issues
55.10.	rot and dilapidation
55.11.	condition of neighbouring property
55.12.	easements
55.13.	External features
	<ul style="list-style-type: none"> • balconies • parapets • bay window openings • entrances
55.14.	party walls
55.15.	property boundaries
55.16.	development rights
55.17.	life-cycle performance of materials
56. Typologies	
56.1.	Solid Walls
56.2.	Cavity Walls
56.3.	Timber Frame
56.4.	Metal Frame
56.5.	Concrete

57. Solutions	
57.1.	External Wall Insulation
	<ul style="list-style-type: none"> • EWI only • EWI + IWI • EWI + CWI • EWI + CWI + IWI
57.2.	Rebuild (support for roof and floors required)
57.3.	Second Skin (new footing required)
57.4.	Thermal bridging
	<ul style="list-style-type: none"> • transition corners between EWI and IWI • EWI and ground floor • EWI and upper floors • EWI and openings • EWI and eaves/roof
57.5.	Dampproofing
57.6.	Ventilation
57.7.	Draughtproofing
	<ul style="list-style-type: none"> • doors • windows • electrical fittings • ceiling to wall joint • pipework to outside
58. Ancillary Works	
58.1.	Window openings
	<ul style="list-style-type: none"> • relocation (within depth of wall, along wall) • cills (extension, removal, overcladding, renewal) • sub-cills (extension, removal, overcladding, renewal)
58.2.	Eaves
	<ul style="list-style-type: none"> • ventilation • extension
58.3.	Drains
	<ul style="list-style-type: none"> • remove • extend • reposition
58.4.	Site circulation
	<ul style="list-style-type: none"> • remove existing pathways • new paving/walkways • stairs (remove existing stair handrails, refix existing stair handrails, protect, repair, refinish) • driveways

58.5. Services

- Telecoms - telephone (lines, junction boxes), internet (cable, lines, routers), cable (boxes, satellite dishes)
- Electricity - wiring, meters (protect, removal and storage, reinstallation, replacement), lighting (protect, removal and storage, reinstallation, replacement)
- Water - pipes, meters (protect, removal and storage, reinstallation, replacement)
- Sewage
- Gas - lines, meters (protect, removal and storage, reinstallation, replacement)
- Security - cameras (protect, removal and storage, reinstallation, replacement), alarms (protect, removal and storage, reinstallation, replacement), motion sensors (protect, removal and storage, reinstallation, replacement), lights (protect, removal and storage, reinstallation, replacement)

58.6. Render

- Excavate to expose DPC
- Existing render (Hammer test, Pressure wash, remove)
- Apply - Render (25mm, 50mm, 75mm, 100mm), Feature bands (75mm, 100mm, 150mm), Beads (starter, corner, stop), 25mm render to reveals (50 wide, 75 wide, 100 wide, 150 wide), working around protrusions

58.7. Facade features

- bay window roofs (flat, pitched)
- plant boxes (protect, remove, replace, reconstruct)
- decorative elements (protect, remove, replace, reconstruct)
- clothes lines (remove, replace, reconstruct)
- recreational equipment (remove, replace)
- plants - climbing plants (protect, remove, replace), hedges (protect, remove, replace), trees (protect, remove, replace)
- existing finishes - tile hung (protect, removal and storage, replacement, reinstallation). pebble dash (protect, removal and storage, replacement, reinstallation)

58.8. Flashings

58.9. Defect treatments

- Lintel failure (repair, replacement, non-existent lintels)
- DPC failure (physical replacement, chemical DPC, electro-osmotic DPC, clay pot/clay tube)
- Brickwork (pointing, resurfacing)
- Subsidence
- Structural defects
- Wall defects (twist, bow, bulge)

59. Opportunities

- 59.1. relocation of doors and windows for better internal layouts
- 59.2. enlargement of window openings for increased daylight and solar access
- 59.3. addition of solar shading devices/features
- 59.4. for second skin solution, opportunity to consolidate appearance of rear extensions

60. Unknowns/Risks

- 60.1. future work might affect performance of current retrofit work
- 60.2. eaves depth
- 60.3. verge depth
- 60.4. heritage issues/conservation area
- 60.5. planning consent
- 60.6. streetscape degradation
- 60.7. existing extensions
- 60.8. allowable thickness limited by eaves depth
- 60.9. roof ventilation strategy
- 60.10. structural soundness - can existing wall support weight of added insulation?
- 60.11. junction/interface with neighbouring property
- 60.12. Product availability - supply and performance
- 60.13. Wind loading
- 60.14. Fire
- 60.15. property boundaries
- 60.16. development rights
- 60.17. warranties
- 60.18. insurance/mortgage
- 60.19. embodied energy of materials

- 60.20. effective life span of materials
- 60.21. future-proofing of performance, i.e. will it be enough to cover climate change?
- 60.22. Effect on streetscape/visual character
- 60.23. Robustness of solution
- 60.24. Durability
- 60.25. Staggered building layouts
- 60.26. Wall rebuild cost risk due to specialist nature and future mortgageability
- 60.27. Wall rebuild excavation risk to existing pipes and connections
- 60.28. Impact on wireless telecommunications
 - internet wireless
 - mobile phone signals
- 60.29. Animal Conservation - bats, badgers, birds, protected species
- 60.30. decayed lime mortar
- 60.31. dry/wet rot within walls
- 60.32. external stairs - EWI not possible

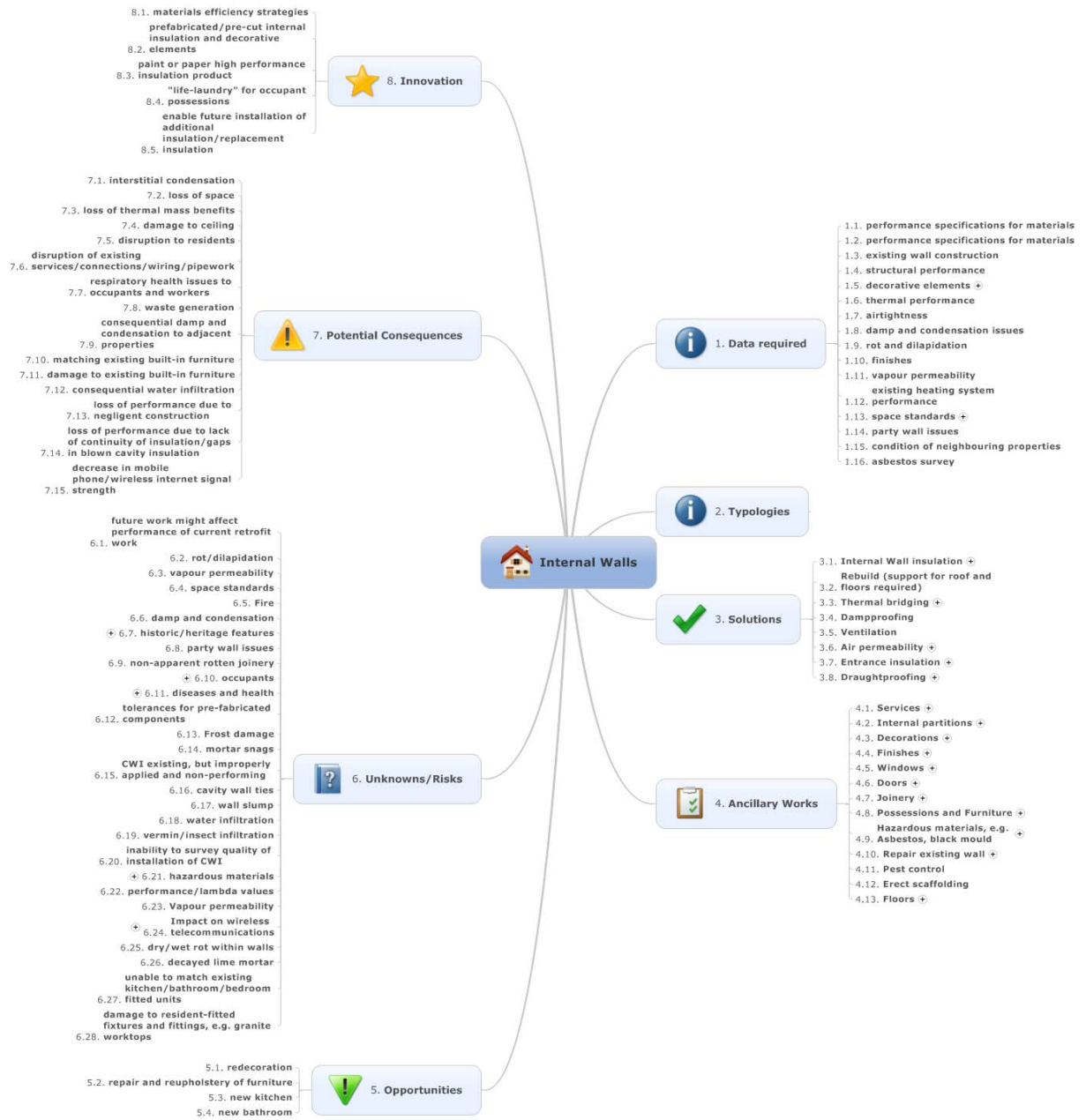
61. Potential Consequences

- 61.1. loss of external circulation spaces
- 61.2. thermal bridging
- 61.3. loss of ventilation, leading to damp and condensation issues
- 61.4. construction delays due to lack of supply
- 61.5. overheating
- 61.6. degradation/de-characterisation of streetscape and neighbourhood
- 61.7. Patchy implementation
- 61.8. Grafitti
- 61.9. Rapid degradation of new untested material
- 61.10. loss of thermal mass benefits
- 61.11. waste generation
- 61.12. consequential water infiltration
- 61.13. Damp and condensation to adjacent properties
- 61.14. destruction of garden/landscaping
- 61.15. decrease in mobile phone/wireless internet signal strength

62. Innovation

- 62.1. all-in-one eaves extender with integrated thermal bridging and eaves ventilation solution
- 62.2. high-performance insulating render approx 2mm
- 62.3. cost benefit and life-cycle analysis of EWI installation
- 62.4. enable future installation of additional insulation/replacement insulation
- 62.5. redefinition of Neighbouring Land Act
- 62.6. Pre-fabricated high thermal performance second skin solution
- 62.7. warm air collection system using translucent EWI material and heat exchanger
- 62.8. all-in-one EWI "gutter cap" solution that neatly fixes junction between edge of roof and extension of EWI beyond roof line

Internal Walls



The following table is a summary of the key issues and tasks involved in retrofit solutions for internal walls:

63. Data required
63.1. performance specifications for materials
63.2. performance specifications for materials
63.3. existing wall construction
63.4. structural performance
63.5. decorative elements
<ul style="list-style-type: none"> • details • suppliers
63.6. thermal performance
63.7. airtightness
63.8. damp and condensation issues
63.9. rot and dilapidation
63.10. finishes
63.11. vapour permeability
63.12. existing heating system performance
63.13. space standards
<ul style="list-style-type: none"> • size of kitchen units • bed dimensions • size of bathroom fittings • size of resident-owned electrical appliances
63.14. party wall issues
63.15. condition of neighbouring properties
63.16. asbestos survey
64. Typologies
64.1. Solid Walls
64.2. Cavity Walls
64.3. Timber Frame
64.4. Metal Frame
64.5. Concrete

65. Solutions
65.1. Internal Wall insulation
<ul style="list-style-type: none"> • IWI + EWI • IWI + CWI • IWI + CWI + EWI
65.2. Rebuild (support for roof and floors required)
65.3. Thermal bridging
<ul style="list-style-type: none"> • IWI and ceiling/eaves • IWI and floor edges • IWI and openings • transition corners between EWI and IWI • electrical sockets and switches • pipework
65.4. Dampproofing
65.5. Ventilation
65.6. Air permeability
<ul style="list-style-type: none"> • Flues - Stacks/Vents (insulation), Chimneys (insulation, fireplace sealing) • cavity sealing • joint sealing • vent brick sealing
65.7. Entrance insulation
<ul style="list-style-type: none"> • porches • lobbies • recessed doors
65.8. Draughtproofing
<ul style="list-style-type: none"> • doors • windows • electrical fittings • ceiling to wall joint

66. Ancillary Works

66.1. Services

- Electrical - meters (removal, relocation, reinstallation, replacement, new smart meter), fuseboxes (removal, relocation, reinstallation, replacement, wiring, rewiring, upgrading sub-standard or hazardous installations, testing, repair, retesting), sockets (rewiring, upgrading sub-standard or hazardous installations, testing, repair, relocation, new, removal, storage, retesting), switches (rewiring, upgrading sub-standard or hazardous installations, testing, repair, relocation, new, removal, storage, retesting), extract fans (rewiring, upgrading sub-standard or hazardous installations, testing, repair, relocation, new, removal, retesting), lighting (rewiring, upgrading sub-standard or hazardous installations, testing, repair, relocation, new, removal, storage, retesting)
- Gas/Heating - meters (removal, relocation, reinstallation, replacement), distribution (testing, repair/seal, upgrading sub-standard or hazardous installations), radiators (removal, relocation, reinstallation, replacement, drain down, refill), central heating (removal, relocation, reinstallation, replacement, drain down, refill), storage heaters (removal, relocation, reinstallation, replacement), boiler and HW storage (remove, protect, store, refit, install new)
- Water - pipes (removal, relocation, replacement, new, seal pipework), water meters (removal, relocation, reinstallation, replacement, new), bath fixtures, sanitary fixtures, kitchen fittings

66.2. Internal partitions

- removal
- relocation
- reconstruction
- finishing

66.3. Decorations

- tasks (protection, restoration, removal, refix, adapt, provide new)

- features - skirtings, quadrants, architraves, window treatments (curtains, blinds, poles, battens), dado rail, picture rail, cornice, coving

66.4. Finishes

- Plastering (removal, replastering)
- Wallcoverings - paint, wallpaper (stripping, reapplication). lincrusta (stripping, reapplication), artex

66.5. Windows

- reveals
- cills
- boards

66.6. Doors

- frames

66.7. Joinery

- tasks (removal, refix, replacement, disposal, adapt)
- items (kitchen base units, kitchen wall units, bathroom base units, bathroom wall units, built-in wardrobes, shelves)

66.8. Possessions and Furniture

- protection
- removal
- storage
- reinstatement

66.9. Hazardous materials, e.g. Asbestos, black mould

- Remove
- Dispose

66.10. Repair existing wall

- dilapidation
- frost damage

66.11. Pest control

66.12. Erect scaffolding

66.13. Floors

- protect
- clean

67. Opportunities

67.1. redecoration

67.2. repair and reupholstery of furniture

67.3. new kitchen

67.4. new bathroom

68. Unknowns/Risks

- 68.1. future work might affect performance of current retrofit work
- 68.2. rot/dilapidation
- 68.3. vapour permeability
- 68.4. space standards
- 68.5. Fire
- 68.6. damp and condensation
- 68.7. historic/heritage features
 - details
 - supply
- 68.8. party wall issues
- 68.9. non-apparent rotten joinery
- 68.10. occupants
 - health and safety (if in occupation)
 - possessions
 - furniture
- 68.11. diseases and health
 - anthrax (medieval properties)
 - vermin-borne diseases
 - mould
- 68.12. tolerances for pre-fabricated components
- 68.13. Frost damage
- 68.14. mortar snags
- 68.15. CWI existing, but improperly applied and non-performing
- 68.16. cavity wall ties
- 68.17. wall slump
- 68.18. water infiltration
- 68.19. vermin/insect infiltration
- 68.20. inability to survey quality of installation of CWI
- 68.21. hazardous materials
 - asbestos
 - urea
 - formaldehyde
- 68.22. performance/lambda values
- 68.23. Vapour permeability
- 68.24. Impact on wireless telecommunications
 - internet wireless
 - mobile phone signals

- 68.25. dry/wet rot within walls
- 68.26. decayed lime mortar
- 68.27. unable to match existing kitchen/bathroom/bedroom fitted units
- 68.28. damage to resident-fitted fixtures and fittings, e.g. granite worktops

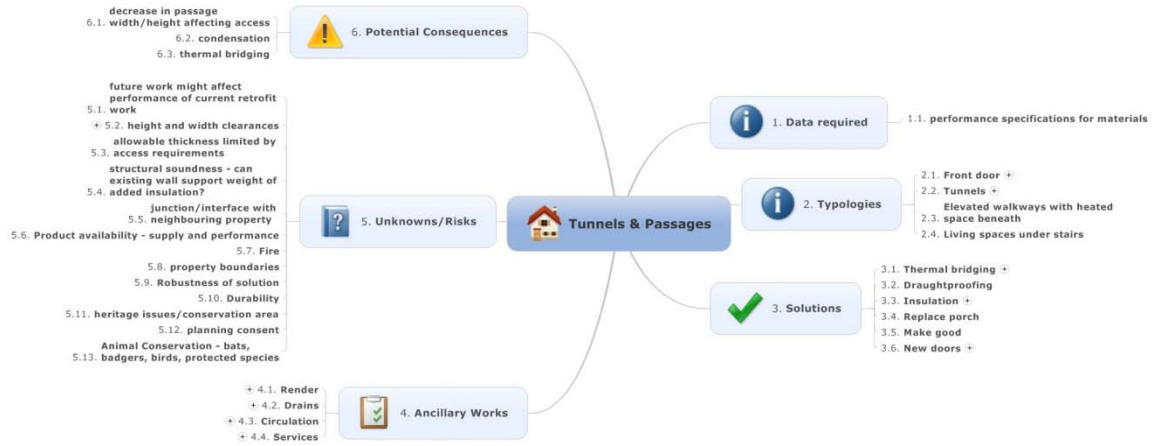
69. Potential Consequences

- 69.1. interstitial condensation
- 69.2. loss of space
- 69.3. loss of thermal mass benefits
- 69.4. damage to ceiling
- 69.5. disruption to residents
- 69.6. disruption of existing services/connections/wiring/pipework
- 69.7. respiratory health issues to occupants and workers
- 69.8. waste generation
- 69.9. consequential damp and condensation to adjacent properties
- 69.10. matching existing built-in furniture
- 69.11. damage to existing built-in furniture
- 69.12. consequential water infiltration
- 69.13. loss of performance due to negligent construction
- 69.14. loss of performance due to lack of continuity of insulation/gaps in blown cavity insulation
- 69.15. decrease in mobile phone/wireless internet signal strength

70. Innovation

- 70.1. materials efficiency strategies
- 70.2. prefabricated/pre-cut internal insulation and decorative elements
- 70.3. paint or paper high performance insulation product
- 70.4. "life-laundry" for occupant possessions
- 70.5. enable future installation of additional insulation/replacement insulation

Tunnels and Passages



The following table is a summary of the key issues and tasks involved in retrofit solutions for tunnels and passages:

71. Data required
71.1. performance specifications for materials
72. Typologies
72.1. Front door
<ul style="list-style-type: none"> • Porches - Enclosed porch (Outside main wall, Inside main wall), Continuous/shared porch, Open porch (Flat canopy, Roofed porch, Stone) • Recessed
72.2. Tunnels
<ul style="list-style-type: none"> • pedestrian passages • vehicular access
72.3. Elevated walkways with heated space beneath
72.4. Living spaces under stairs
73. Solutions
73.1. Thermal bridging
<ul style="list-style-type: none"> • transition corners between EWI and IWI • EWI and soffit • EWI and openings • IWI and soffit • IWI and openings • IWI and porch roof • EWI and porch roof
73.2. Draughtproofing
73.3. Insulation
<ul style="list-style-type: none"> • EWI tunnel walls and/or soffit • IWI tunnel walls and/or soffit • IWI recessed door entrance/porch walls • Insulate soffit of recessed door entrance/porch
73.4. Replace porch
73.5. Make good
73.6. New doors
<ul style="list-style-type: none"> • replace porch door with energy efficient door • install new doors at tunnel openings • enclose open porch and add external door

74. Ancillary Works

74.1. Render
<ul style="list-style-type: none"> • Excavate to expose DPC • Existing render (Hammer test, Pressure wash, remove) • Apply - Render (25mm, 50mm, 75mm, 100mm), Feature bands (75mm, 100mm, 150mm), Beads (starter, corner, stop), 25mm render to reveals (50 wide, 75 wide, 100 wide, 150 wide), working around protrusions
74.2. Drains
<ul style="list-style-type: none"> • remove • extend • reposition
74.3. Circulation
<ul style="list-style-type: none"> • remove existing pathways • new paving/walkways
74.4. Services
<ul style="list-style-type: none"> • Telecoms • Electricity (wiring, meters) • Water Supply • Sewage

75. Unknowns/Risks

- 75.1. future work might affect performance of current retrofit work
- 75.2. height and width clearances
 - pedestrian - prams, wheelchairs, garden equipment
 - vehicles
- 75.3. allowable thickness limited by access requirements
- 75.4. structural soundness - can existing wall support weight of added insulation?
- 75.5. junction/interface with neighbouring property
- 75.6. Product availability - supply and performance
- 75.7. Fire
- 75.8. property boundaries
- 75.9. Robustness of solution
- 75.10. Durability
- 75.11. heritage issues/conservation area
- 75.12. planning consent
- 75.13. Animal Conservation - bats, badgers, birds, protected species

76. Potential Consequences

- 76.1. decrease in passage width/height affecting access
- 76.2. condensation
- 76.3. thermal bridging

Extensions



The following table is a summary of the key issues and tasks involved in retrofit solutions for extensions:

77. Data required	
77.1.	performance specifications for materials
77.2.	Structural integrity of room/wall to be extended
77.3.	heating system schematics/radiator locations
77.4.	External spaces/access pathways
77.5.	location data - orientation, solar path, solar access, wind speed and direction
77.6.	boiler capacity
78. Typologies	
78.1.	heated spaces
	<ul style="list-style-type: none"> • Room enlargements • Additional rooms • Garage conversions
78.2.	non-heated spaces
	<ul style="list-style-type: none"> • Conservatories • Sun-rooms • Garages (closed, car ports) • Porches • Verandas • Sheds/storage

79. Solutions	
79.1.	install/build extension
79.2.	insulation
	<ul style="list-style-type: none"> • existing wall (external, internal) • new walls (integrated, external, internal) • floor (ground floor, floor space above entrances) • roof • walls in between heated and unheated spaces
79.3.	ventilation
	<ul style="list-style-type: none"> • resolve ventilation features for existing roof • establish ventilation features for extension (background ventilation, purge ventilations, extract ventilation)
79.4.	thermal bridging
	<ul style="list-style-type: none"> • extension wall to existing wall • extension roof to existing roof • extension roof to existing wall
79.5.	Waterproofing and dampproofing
	<ul style="list-style-type: none"> • roof • floor • openings
79.6.	airtightness
79.7.	heating systems
	<ul style="list-style-type: none"> • new radiators • underfloor heating system • new pipes • room heaters
79.8.	energy efficient glazing
	<ul style="list-style-type: none"> • install • upgrade • make good
79.9.	overheating solutions for conservatories
	<ul style="list-style-type: none"> • shading devices • blinds • fans

80. Ancillary Works

80.1. Existing Walls

- Remove
- Clean/prepare

80.2. Prepare site

80.3. Services

- Electricity (re-wiring, new outlets/circuits, move meters (if affected), new energy-efficient lights)
- Plumbing (re-routing pipework, new pipework, new fixtures and fittings, move meters (if affected))

81. Opportunities

- 81.1. south facing extension could be an opportunity for roof-integrated PV/solar thermal

82. Unknowns/Risks

- 82.1. Thermal bridging
- 82.2. access to services
- 82.3. easements
- 82.4. planning constraints
- 82.5. neighbours
- 82.6. Delivered airtightness of extension product
- 82.7. future work might affect performance of current retrofit work
- 82.8. Structurally unsound existing extensions
- 82.9. non-compliance with building regs
- illegal extensions
 - external door removed from conservatory
 - radiators within conservatories
- 82.10. boiler capacity not enough to cover added heated space
- 82.11. Animal Conservation - bats, badgers, birds, protected species

83. Potential Consequences

- 83.1. structural collapse
- 83.2. decrease in thermal performance of entire property
- 83.3. overheating
- 83.4. decrease in daylight/solar access
- 83.5. negative impact on neighbours
- 83.6. disruption/damage to pipework/electricals during excavation
- 83.7. creation of cold spots in existing house
- 83.8. decrease in ventilation rate/blocking ventilation routes

84. Innovation

- 84.1. pre-fabricated habitable room modules with integrated insulation and thermal bridging solutions

Technologies



The following table is a summary of the key issues and tasks related to systems and technologies for retrofit application:

85. Data required

85.1. performance specifications for technologies and systems

86. Solutions and Opportunities

86.1. heat recovery systems

- Shower-Save
- waste heat

86.2. warm air collectors

86.3. solar thermal hot water systems

86.4. high-efficiency boiler

86.5. heat pumps

86.6. underfloor heating

86.7. smart meters

86.8. thermal storage

87. Ancillary Works

88. Opportunities

89. Unknowns/Risks

89.1. specialist resident-installed heating systems

89.2. photovoltaic/solar thermal system connections

90. Potential Consequences

90.1. damage to specialist heating systems installed by resident

90.2. damage to photovoltaic/solar thermal systems

91. Innovation

House Types - Applicability of Solutions

This table compares the identified technical solutions against the twelve most likely house type candidates for refurbishment, based on the typical construction of that house type and obvious constraints related to heritage issues and the aesthetic visibility of that solution (English Housing stock only)

Applicability

■ problematic
■ not applicable

	HOUSE TYPES											
	Pre-1919, mid terrace	1919-1944, semi detached	1945-1964, semi detached	Post-1980, detached	1965-1980, semi detached	1965-1980, purpose built flat, low rise	Post-1980, purpose built flat, low rise	1965-1980, detached	Pre-1919, semi detached	1965-1980, bungalow	Pre-1919, converted flat	1919-1944, mid terrace
1 Ground Floor Insulation												
2 Ground Floor dampproofing	■					■	■		■		■	
3 Loft Insulation												
4 Re-roofing	■											
5 Room in Roof						■	■					
6 Chimney sealing/draughtproofing						■	■					
7 Replacement doors and windows	■			■		■	■		■		■	
8 Draughtproofing doors and windows												
9 Repair/improvement of doors and windows	■								■		■	
10 External Wall Insulation												
11 Cavity Wall Insulation												
12 Internal Wall Insulation												
13 Tank and pipe Insulation												
14 Rebuild Wall												
15 Thermal bridging and Condensation solutions												
16 Airtightness												
17 Thermal doors for tunnels and passages												
18 Insulation for tunnels and passages												
19 Thermal improvement of existing extensions												
20 Add porch	■								■		■	
21 MVHR/heat recovery installation	■								■		■	
22 New high-efficiency boiler installation												
23 New Solar hot water system	■										■	
30 Photovoltaics	■										■	
24 Underfloor heating												
25 Improve Controls												
26 Smart meters												
27 Heat pump												
28 Rainwater collection system						■	■				■	
29 Greywater recycling system												
30 Roof lights/Solar pipes												
31 New unheated extension												
32 New kitchen/bathroom												
33 New fitted wardrobes and shelves												
34 Interior redecoration - finishes												
35 Garden landscaping												

The Evaluation Matrices

Traditionally when we talk about technical solutions, experts talk about only design, construction and performance issues. But the nature of the Thermal Efficiency project is it's more wholistic approach, going beyond just design and construction and looking at supply chain, customer acceptance and government policy. We looked at the selected technical solutions according to five "families" of criteria:

- Design and Construction (EM1)
- Supply Chain (EM2)
- Customer Acceptance (EM3)
- Policy (EM4), and
- Cost (EM5)

We then identified six sub-issues under each of these issues by which to evaluate each technical solution, assigning each item with a score of 1-10, with 1 implying that it is detrimental to the success of mass retrofit and 10 implying that it will facilitate a mass retrofit rollout. These scores were then averaged out in order to give us an indication of the "easy wins" that would form the basis for our whole house solutions. Double weighting was given to the most important sub-issues per category, and these are the following:

- Design and Construction - visual impact (streetscape), energy reduction potential
- Supply Chain - potential for off-site/automation
- Customer Acceptance - disruption
- Policy - carbon reduction effectiveness
- Cost - capital cost

The final chart in the series shows the "Top 10" interventions that emerged from the analysis, as well as those with low values. These numbers and figures are based on industry and research experience and should only be used as a decision tool and should by no means be treated as the final word on the matter.

EM1 DESIGN AND CONSTRUCTION

EM1		Design and Construction					
Visual Impact (streetscape)		Range of Aesthetic Choices	Reduction of Energy Demand	Ease of Installation	Waste Generation	Lead time for Materials	
1 - will not affect streetscape		1 - limited palette	1 - no impact on energy demand reduction	1 - difficult to install	1 - high volumes of waste generated	1 - high probability of procurement delays	
10 - could significantly affect streetscape on mass scale		10 - wide range of choices	10 - high degree of energy demand reduction	10 - easy to install	10 - low volumes of waste generated	10 - rapid procurement and delivery on site	
1	Ground Floor Insulation	10	1	3	2	3	9
2	Ground Floor dampproofing	10	1	3	4	5	10
3	Loft Insulation	10	1	7	7	10	9
4	Re-roofing	3	5	7	5	1	8
5	Room in Roof	6	7	1	1	4	7
6	Chimney sealing/draughtproofing	8	1	1	9	10	10
7	Replacement doors and windows	8	7	5	8	2	3
8	Draughtproofing doors and windows	8	1	6	10	10	10
9	Repair/improvement of doors and windows	8	1	4	10	10	9
10	External Wall Insulation	3	8	9	7	6	5
11	Cavity Wall Insulation	9	1	7	9	10	10
12	Internal Wall Insulation	9	8	7	2	6	4
13	Tank and pipe Insulation	10	1	5	7	4	10
14	Rebuild Wall	1	9	8	5	6	6
15	Thermal bridging and Condensation solutions	10	1	4	4	8	8
16	Airtightness	10	1	7	7	7	9
17	Thermal doors for tunnels and passages	4	7	3	8	9	3
18	Insulation for tunnels and passages	4	1	3	4	5	8
19	Thermal improvement of existing extensions	7	6	2	7	9	9
20	Add porch	3	8	5	5	6	7
21	MVHR/heat recovery installation	8	1	5	5	9	5
22	New high-efficiency boiler installation	8	2	6	5	8	9
23	New Solar hot water system	3	2	9	2	6	3
30	Photovoltaics	3	2	8	6	9	5
24	Underfloor heating	10	1	4	2	3	3
25	Improve Controls	10	5	5	10	10	9
26	Smart meters	10	5	4	10	10	9
27	Heat pump	8	1	4	5	8	8
28	Rainwater collection system	5	3	1	7	9	9
29	Greywater recycling system	5	2	1	7	9	9
30	Roof lights/Solar pipes	5	3	6	6	9	5
31	Conservatory/sunroom	6	8	1	6	6	6
32	New kitchen/bathroom	10	9	5	5	5	3
33	New fitted wardrobes and shelves	10	9	1	9	9	10
34	Interior redecoration - finishes	10	9	1	8	7	8
35	Garden landscaping	5	9	1	8	8	10

EM2 SUPPLY CHAIN

		EM2 Supply Chain					
		Generic Material Available eg: Newbuild	Effective Retrofit Products (installable)	Availability Of skilled Installers	Robust Installation Methods / Processes	Potential for Off- Site / Automation	Difficulty to upscale capacity
		1 - Almost impossible to find	1 - No-one	1 - Total Disatisfaction	1 - Craft solution	1 - More than 2yrs	
		10 - Effective & Available	10 - Many alternatives	10 - Right first time	10 - Major quality / time / cost improvement	10 - Instantaneous	
1	Ground Floor Insulation	10	4	6	5	6	5
2	Ground Floor dampproofing	10	8	8	6	4	9
3	Loft Insulation	10	8	9	7	7	9
4	Re-roofing	10	10	10	9	9	7
5	Room in Roof	6	5	9	6	9	6
6	Chimney sealing/draughtproofing	7	7	5	7	5	9
7	Replacement doors and windows	9	9	10	9	5	7
8	Draughtproofing doors and windows	10	7	7	7	5	8
9	Repair/improvement of doors and windows	10	8	7	9	7	7
10	External Wall Insulation	8	6	7	6	8	6
11	Cavity Wall Insulation	7	6	9	7	7	6
12	Internal Wall Insulation	7	5	6	5	8	5
13	Tank and pipe Insulation	10	10	10	9	8	8
14	Rebuild Wall	7	7	7	9	8	5
15	Thermal bridging and Condensation solutions	7	7	5	4	7	6
16	Airtightness	8	6	5	5	5	7
17	Thermal doors for tunnels and passages	8	7	8	8	5	8
18	Insulation for tunnels and passages	7	6	8	7	8	6
19	Thermal improvement of existing extensions	10	7	8	8	5	8
20	Add porch	10	8	9	8	9	7
21	MVHR/heat recovery installation	7	6	6	6	7	5
22	New high-efficiency boiler installation	9	8	8	9	7	7
23	New Solar hot water system	7	6	6	7	8	6
30	Photovoltaics	8	8	9	8	7	3
24	Underfloor heating	9	7	7	7	6	7
25	Improve Controls	7	7	5	8	5	6
26	Smart meters	7	6	5	8	5	6
27	Heat pump	6	6	6	6	7	4
28	Rainwater collection system	8	7	6	8	6	6
29	Greywater recycling system	6	5	4	5	7	5
30	Roof lights/Solar pipes	9	9	8	9	6	7
31	Conservatory/sunroom	10	10	10	9	9	6
32	New kitchen/bathroom	9	9	10	9	7	7
33	New fitted wardrobes and shelves	10	8	9	9	8	7
34	Interior redecoration - finishes	10	9	10	10	6	9
35	Garden landscaping	10	10	10	8	5	9

EM3 CUSTOMER ACCEPTANCE

	EM3	Customer Acceptance			Disruption	Visual Impact (householder)	
	Ease of use	Awareness	Lifestyle impact	Desirability			
	1 - highly demanding to use 10 - simple to use/ no usage required	1 - unheard of/ perception of risk 10 - publicly well known and accepted	1 - major lifestyle change required 10 - fit and forget	1 - active opposition 10 - highly desirable			
					1 - decant required 10 - stress-free, occupant in residence possible	1 - high visual impact 10 - no visual impact	
1	Ground Floor Insulation	10	6	10	6	2	8
2	Ground Floor dampproofing	10	7	10	7	9	10
3	Loft Insulation	9	10	10	8	6	10
4	Re-roofing	10	10	10	7	7	5
5	Room in Roof	10	10	9	10	2	10
6	Chimney sealing/draughtproofing	9	7	8	6	6	8
7	Replacement doors and windows	9	10	10	10	8	3
8	Draughtproofing doors and windows	8	9	7	8	8	10
9	Repair/improvement of doors and windows	10	10	10	8	8	6
10	External Wall Insulation	10	4	10	2	9	1
11	Cavity Wall Insulation	10	6	10	5	9	10
12	Internal Wall Insulation	10	4	10	3	3	6
13	Tank and pipe Insulation	10	10	10	8	5	9
14	Rebuild Wall	10	9	10	6	1	6
15	Thermal bridging and Condensation solutions	10	3	10	5	4	8
16	Airtightness	10	6	7	7	6	8
17	Thermal doors for tunnels and passages	10	3	10	4	10	4
18	Insulation for tunnels and passages	10	3	10	4	9	9
19	Thermal improvement of existing extensions	10	8	10	8	7	9
20	Add porch	10	8	10	7	5	3
21	MVHR/heat recovery installation	6	2	7	4	5	8
22	New high-efficiency boiler installation	8	9	8	9	7	9
23	New Solar hot water system	6	6	6	6	7	9
30	Photovoltaics	8	6	7	9	8	8
24	Underfloor heating	7	6	7	8	2	9
25	Improve Controls	8	7	5	5	7	9
26	Smart meters	7	5	6	5	7	9
27	Heat pump	6	3	6	4	5	9
28	Rainwater collection system	8	8	9	8	8	8
29	Greywater recycling system	8	4	8	4	8	8
30	Roof lights/Solar pipes	9	6	8	6	8	8
31	Conservatory/sunroom	10	10	10	8	1	1
32	New kitchen/bathroom	10	10	10	10	6	1
33	New fitted wardrobes and shelves	10	10	10	10	6	6
34	Interior redecoration - finishes	10	10	10	9	1	1
35	Garden landscaping	10	10	10	8	4	4

EM4 POLICY

	EM4 Policy						
	Potential for providing funding mechanisms	Potential for industry subsidy	Quality Assurance of install and products	Carbon Reduction Effectiveness to achieve targets	Planning	Health and Safety	
	1 - not likely to be funded	1 - least effective for property improvement	1 - difficult to QA	1 - worst bang for buck	1 - subject to planning constraints	1 - high risk for health and safety	
	10 - likely to be funded	10 - most effective for property improvement	10 - easy to QA	10 - best bang for buck	10 - no planning constraints	10 - low risk for health and safety	
1	Ground Floor Insulation	5	1	5	5	10	9
2	Ground Floor dampproofing	1	1	5	1	10	9
3	Loft Insulation	10	2	10	10	10	4
4	Re-roofing	1	1	5	5	5	2
5	Room in Roof	2	1	5	8	5	2
6	Chimney sealing/draughtproofing	1	1	3	4	10	5
7	Replacement doors and windows	8	1	4	4	6	5
8	Draughtproofing doors and windows	8	1	3	4	10	9
9	Repair/improvement of doors and windows	7	1	4	4	10	8
10	External Wall Insulation	10	5	10	10	3	3
11	Cavity Wall Insulation	10	5	8	10	10	6
12	Internal Wall Insulation	10	5	10	10	10	7
13	Tank and pipe Insulation	10	3	8	6	10	9
14	Rebuild Wall	1	1	4	2	7	4
15	Thermal bridging and Condensation solutions	5	1	8	5	9	6
16	Airtightness	5	1	8	5	10	6
17	Thermal doors for tunnels and passages	3	1	4	4	8	9
18	Insulation for tunnels and passages	8	3	7	4	9	6
19	Thermal improvement of existing extensions	2	1	4	2	7	5
20	Add porch	4	1	4	3	6	6
21	MVHR/heat recovery installation	5	1	5	3	10	8
22	New high-efficiency boiler installation	8	5	8	8	10	9
23	New Solar hot water system	8	1	8	8	6	3
30	Photovoltaics	5	1	8	8	6	3
24	Underfloor heating	4	1	4	4	10	7
25	Improve Controls	5	5	10	5	10	8
26	Smart meters	8	3	10	5	10	8
27	Heat pump	5	1	8	7	6	8
28	Rainwater collection system	1	1	1	1	10	4
29	Greywater recycling system	1	1	1	1	10	5
30	Roof lights/Solar pipes	2	1	5	4	10	7
31	Conservatory/sunroom	2	1	6	3	8	7
32	New kitchen/bathroom	1	1	2	1	10	1
33	New fitted wardrobes and shelves	1	1	2	1	10	5
34	Interior redecoration - finishes	1	1	1	1	10	5
35	Garden landscaping	1	1	1	1	10	5

EM5 COST

	EM5						
	Capital Cost	Cost Evaluation				Duration of Work	
		Cost of Ancillary Works	Cost Escalation Risk	Maintenance Costs	Availability of Funding		
	1 - high capital cost	1 - high cost of ancillary works	1 - high risk of cost escalation	1 - high maintenance costs	1 - low availability of funding	1 - long programme of work	
	10 - low capital cost	10 - low cost of ancillary works	10 - low risk of cost escalation	10 - low maintenance costs	10 - funding available	10 - rapid installation	
1	Ground Floor Insulation	8	4	4	10	5	3
2	Ground Floor dampproofing	7	4	4	10	2	3
3	Loft Insulation	10	8	9	10	8	9
4	Re-roofing	6	7	8	9	2	6
5	Room in Roof	5	6	7	10	1	4
6	Chimney sealing/draughtproofing	7	9	9	10	1	9
7	Replacement doors and windows	6	8	8	9	5	5
8	Draughtproofing doors and windows	9	8	9	9	7	10
9	Repair/improvement of doors and windows	8	8	9	9	2	9
10	External Wall Insulation	5	8	7	10	3	3
11	Cavity Wall Insulation	10	9	10	10	10	10
12	Internal Wall Insulation	8	4	8	9	2	3
13	Tank and pipe Insulation	8	8	8	6	2	9
14	Rebuild Wall	6	5	7	10	1	6
15	Thermal bridging and Condensation solutions	7	7	7	10	6	8
16	Airtightness	8	8	8	10	5	8
17	Thermal doors for tunnels and passages	9	9	10	9	1	9
18	Insulation for tunnels and passages	8	9	9	9	1	8
19	Thermal improvement of existing extensions	8	7	8	9	2	9
20	Add porch	8	8	9	10	1	7
21	MVHR/heat recovery installation	6	4	5	7	2	6
22	New high-efficiency boiler installation	7	7	7	8	5	9
23	New Solar hot water system	5	7	7	9	4	4
30	Photovoltaics	3	5	6	7	7	6
24	Underfloor heating	6	7	8	10	1	3
25	Improve Controls	7	7	9	10	5	8
26	Smart meters	6	7	9	10	5	8
27	Heat pump	5	5	7	9	1	8
28	Rainwater collection system	8	8	9	9	3	9
29	Greywater recycling system	6	6	6	8	2	8
30	Roof lights/Solar pipes	7	6	6	9	2	6
31	Conservatory/sunroom	5	6	7	9	2	6
32	New kitchen/bathroom	8	8	8	9	5	4
33	New fitted wardrobes and shelves	9	9	9	10	1	10
34	Interior redecoration - finishes	9	8	9	9	1	9
35	Garden landscaping	8	8	9	8	1	9

EVALUATION MATRICES SUMMARY CHART

Evaluation Matrices

	Overall Score	Rank
1 Ground Floor Insulation	5.8	
2 Ground Floor dampproofing	6.2	
3 Loft Insulation	8.3	1st
4 Re-roofing	6.3	
5 Room in Roof	5.7	
6 Chimney sealing/draughtproofing	6.2	
7 Replacement doors and windows	6.6	
8 Draughtproofing doors and windows	7.4	4th
9 Repair/improvement of doors and windows	7.2	5th
10 External Wall Insulation	6.6	10th
11 Cavity Wall Insulation	8.3	1st
12 Internal Wall Insulation	6.6	10th
13 Tank and pipe Insulation	7.6	2nd
14 Rebuild Wall	5.6	
15 Thermal bridging and Condensation solutions	6.3	
16 Airtightness	6.8	9th
17 Thermal doors for tunnels and passages	6.4	
18 Insulation for tunnels and passages	6.4	
19 Thermal improvement of existing extensions	6.5	
20 Add porch	6.3	
21 MVHR/heat recovery installation	5.5	
22 New high-efficiency boiler installation	7.5	3rd
23 New Solar hot water system	6.0	
30 Photovoltaics	6.2	
24 Underfloor heating	5.6	
25 Improve Controls	7.1	6th
26 Smart meters	6.9	8th
27 Heat pump	5.8	
28 Rainwater collection system	6.0	
29 Greywater recycling system	5.2	
30 Roof lights/Solar pipes	6.3	
31 Conservatory/sunroom	5.9	
32 New kitchen/bathroom	6.4	
33 New fitted wardrobes and shelves	7.1	7th
34 Interior redecoration - finishes	6.4	
35 Garden landscaping	6.3	

The Synergy Matrices

It is likely that some of our stakeholders may be financially unable to undertake whole house solutions and that either a room-by-room approach or a phased programme of work may need to be presented as an alternative to a one-off, let's do it all today approach, which would be the most effective and easy to deliver but which represents a substantial upfront cost and a significant amount of disruption to the owner/occupants.

The following synergy matrices provide a tool to visualise which improvements are best done together, within the same retrofit session in order to get the maximum benefit of the installation. We have chosen a variety of interventions that are a mixture of ones that are most commonly undertaken by homeowners, ones that make the most impact in a thermal efficiency sense, and some gadgets and gizmos that relate to energy efficiency.

Thermal Interventions

1	Ground Floor Insulation
2	Ground Floor dampproofing
3	Loft Insulation
4	Re-roofing
5	Room in Roof
6	Chimney sealing/draughtproofing
7	Replacement doors and windows
8	Draughtproofing doors and windows
9	Repair/improvement of doors and windows
10	External Wall Insulation
11	Cavity Wall Insulation
12	Internal Wall Insulation
13	Tank and pipe Insulation
14	Rebuild Wall
15	Thermal bridging and Condensation solutions
16	Airtightness
17	Thermal doors for tunnels and passages
18	Insulation for tunnels and passages
19	Thermal improvement of existing extensions
20	Add porch

Systems

21	MVHR/heat recovery installation
22	New high-efficiency boiler installation
23	New Solar hot water system
30	Photovoltaics
24	Underfloor heating
25	Improve Controls
26	Smart meters
27	Heat pump

Opportunities/Incentive mechanisms

28	Rainwater collection system
29	Greywater recycling system
30	Roof lights/Solar pipes
31	New unheated extension
32	New kitchen/bathroom
33	New fitted wardrobes and shelves
34	Interior redecoration - finishes
35	Garden landscaping

In order to evaluate these interventions, we looked at five factors for the synergy matrices:



SM1 AVOIDANCE OF FUTURE PERFORMANCE RISK

This synergy matrix is based on the fact that one of the biggest risks to any retrofit exercise is the robustness of the solution in the face of DIY or later work done by another contractor, which may affect the thermal bridging, condensation or airtightness performance of previously installed components when new interventions are installed. For example, if new doors and windows are installed by the owner in the future, how will this affect the performance of the internal or external wall insulation that we have put in place today? Interventions that are best done together in order to avoid future performance risk are indicated by a red square with the letter "R" in it.

If Solution A and Solution B are not done together, is there any risk that the installation of one or the other at a later date will compromise the performance of the previously installed solution?



SM2 COST EFFECTIVENESS

Every time a contractor goes on site to deliver a job, certain preliminary works need to be set up that will be the same across every project and can be used for several components. Therefore doing two separate pieces of work at different points in time which would have had shared prelims means that the cost for those shared facilities is doubled - how can this be avoided? This chart show items that have shared resources - scaffolding for example - that would be most cost-effective when done in tandem. Interventions that provide cost efficiencies when done together are indicated by an orange square with the letter "C" in it.

If Solution A and Solution B are done at the same time, is it significantly cheaper to do so rather than have the other solution done at a later date?



SM3 ENHANCED PERFORMANCE

When things are done together then clever integrated solutions can emerge at the junctions and interfaces between interventions, which mean better performance at that junction as opposed to a solution bolted on to a previously installed solution. This chart shows where the synergies are where clever details and products have been created for two components that are installed at the same time, indicated by a green square with the letter "P" in it.

If Solution A and Solution B are done at the same time, does the assembly as a whole perform better in a way that you would never be able to achieve if they are done separately?



SM4 WASTE MINIMISATION

Mass scale may mean pre-fabrication - where are the synergies between these interventions where doing them concurrently or simultaneously means that less waste is generated from demolition, cutting materials on site and disposing of materials that may be superseded in future installations? These synergies are indicated by a blue square with a "W" in it.

If Solution A and Solution B are done at the same time, is there a potential for implementing construction/prefabrication methods that will effectively minimize waste on site?



SM5 DISRUPTION MINIMISATION

In general, the more work is done at the same time, the more disruption occurs in the short term but it also means lesser return work over a longer period. This graphic shows where disruption can be minimized over the long term by ensuring that work affecting similar areas of the house or similar components is done at the same time so that it doesn't need to be ripped up again in the future to install another intervention. These synergies are indicated by a purple square with a "D" in it.

On a room-by-room, occupant in residence scenario, which pairs of scenarios can be grouped together to ensure that the disruption is localized? If the interventions tend to occur in the same area of the house, place a highlight in the box.

These five synergies have been analysed in isolation from each other and subsequently presented in a single graph. The graphs that follows show the results of this analysis - synergies that satisfy all five criteria can be considered the "no-brainers" - if we are going to propose to undertake one of the interventions then it would be a sensible approach to undertake the other one as well.

Synergy Matrix

	FLOORS				ROOFS			
	Ground floor insulation	Ground floor dampproofing	Loft Insulation	Re-roofing	Room in roof	Chimney sealing		
Ground floor insulation	R C P W D							
Ground floor dampproofing								
Loft Insulation			R C P W D					
Re-roofing			R C P W D					
Room in Roof				R C P W D				
Chimney sealing								
Replace doors and windows								
Draughtproofing								
Repair of doors and windows								
External Wall Insulation	P W D R		P W	R C P	R C P			
Cavity Wall Insulation	W							W
Internal Wall Insulation	R P D		P					
Tank and pipe insulation								
Rebuild Wall	R P		P					
Thermal bridging and condensation solutions	P W D R		C P W D	R C P W D	R C P W D			W
Airtightness	P		P					
Thermal doors for tunnels and passages								
Insulation for tunnels and passages	P		P					
Thermal improvement of existing extensions	P		C P					
New porch space								
MVHR installation								
New high-efficiency boiler								
New solar hot water system								
Photovoltaics								
Underfloor heating	R C W D	C P W D						
Improve controls								
Smart meters								
Heat pump	R							
Rainwater collection system								
Greywater recycling system								
Roof lights/ solar pipes								
Conservatory/ sunroom	R P W D R C P W D		R C P W D	R C P W D	R C P W D			D
New kitchen/bathroom	P							
New fitted wardrobes and shelves								
Interior redecoration - finishes	R							
Garden landscaping	P							

	OPENINGS				WALLS																									
	Replace doors and windows																													
	Draughtproofing				Repair of doors and windows				External wall insulation				Cavity wall insulation				Internal wall insulation													
	R	C	P	W	D	R	C	P	W	D	R	C	P	W	D	R	C	P	W	D	R	C	P	W	D	R	C	P	W	D
Draughtproofing	R	C	P	W	D	R	C	P	W	D																				
Repair of doors and windows				W					W																					
External Wall Insulation	R	C	P	W	D	R	C	P	W	D																				
Cavity Wall Insulation	R	C	P		D	R				D																				
Internal Wall Insulation	R	C	P	W	D	R	C	P	W	D																				
Tank and pipe insulation																														
Rebuild Wall	R		P	W	D					D																				
Thermal bridging and condensation solutions	R	C	P	W	D				W																					
Airtightness	R	C	P	W	D	R	C	P	W	D																				
Thermal doors for tunnels and passages				W					W																					
Insulation for tunnels and passages																														
Thermal improvement of existing extensions	R	C		W	D				W	D																				
New porch space	R	C		W	D				W	D																				
MVHR installation	R		P			R		P																						
New high-efficiency boiler				P					P																					
New solar hot water system				P					P																					
Photovoltaics																														
Underfloor heating				P					P																					
Improve controls																														
Smart meters																														
Heat pump																														
Rainwater collection system																														
Greywater recycling system																														
Roof lights/solar pipes																														
Conservatory/sunroom	R	C	P	W	D				W	D																				
New kitchen/bathroom					D				W	D																				
New fitted wardrobes and shelves					D				W	D																				
Interior redecoration - finishes	R	C		W	D				W	D																				
Garden landscaping																														

	OTHER FABRIC				PASSAGES				EXTENSIONS							
	Tank and pipe insulation		Rebuild wall		Thermal bridging and condensation solutions		Airtightness		Thermal doors for tunnels and passages		Insulation for tunnels and passages		Thermal improvement of existing extensions		New porch space	
Rebuild Wall	R		P	W	D											
Thermal bridging and condensation solutions		P	W		D	R	C	P	W	D						
Airtightness		P	W		D	R	C	P	W	D						
Thermal doors for tunnels and passages																
Insulation for tunnels and passages																
Thermal improvement of existing extensions																
New porch space																
MVHR installation	R	P				R	C	P	W	D						
New high-efficiency boiler	R	C	P	W	D	R	C	P	W	D						
New solar hot water system																
Photovoltaics																
Underfloor heating																
Improve controls																
Smart meters																
Heat pump																
Rainwater collection system																
Greywater recycling system																
Roof lights/solar pipes																
Conservatory/sunroom																
New kitchen/bathroom																
New fitted wardrobes and shelves																
Interior redecoration - finishes																
Garden landscaping																

SYSTEMS

	MVHR installation			New high-efficiency boiler			New solar hot water system			Photovoltaics			Underfloor heating			Improve controls			Smart meters			Heat Pump														
New high-efficiency boiler	C	P	W				R	C	P	W	D																									
New solar hot water system				C			C	C	P	W	D	C	P	W	D																					
Photovoltaics												C						C	W																	
Underfloor heating																																				
Improve controls																																				
Smart meters																																				
Heat pump																																				
Rainwater collection system				C																																
Greywater recycling system																																				
Roof lights/solar pipes																																				
Conservatory/sunroom	R	C	P																																	
New kitchen/bathroom	R																																			
New fitted wardrobes and shelves																																				
Interior redecoration - finishes	R																																			
Garden landscaping			P																																	

OPPORTUNITIES/INCENTIVES

	Rainwater collection system				Greywater recycling system				Rooflights/solar pipes				Conservatory/sunroom				New kitchen/bathroom				Newfitted wardrobes and shelves				Interior redecoration - finishes									
Greywater recycling system	C	C	R		D				C	C	R																							
Roof lights/solar pipes																																		
Conservatory/sunroom																																		
New kitchen/bathroom																																		
New fitted wardrobes and shelves																																		
Interior redecoration - finishes																																		
Garden landscaping																																		

Findings and Conclusions

EVALUATION MATRICES

The final Evaluation Matrix shows that the "Top 5" interventions are the ones that are already 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. Of interest are the thermal interventions that follow - improvement of building control systems, smart meters, airtightness, internal wall insulation and external wall insulation complete the "Top 10".

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.

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
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- 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.

It is worth noting that these synergies are two-way - for example if the Top 10 item is the primary intervention it would be worth considering accelerating the programme for the synergetic interventions so that they are done within the same retrofit exercise. However, of course if the synergetic intervention is one that is not likely to ever be implemented on the property then it should not be considered. If you look at it the other way around, if the homeowner is planning to install a new kitchen or bathroom in the near future then it is a perfect opportunity to pitch the argument for internal wall insulation.