Retrofit for the Future: analysis of cost data

For the Technology Strategy Board

Final Report

Foreword

The Retrofit for the Future programme has accelerated the emerging domestic retrofit sector in the UK. In 2009, when Retrofit for the Future started, the Government's energy efficiency loan scheme (Green Deal) was not available and the Energy Company Obligation (ECO) was yet to commence. There was however a realisation that the existing housing stock had to be improved and that this would open up an enormous new business market. Retrofit for the Future developed into one of the highlight achievements of the Technology Strategy Board.

With the support of the Homes and Communities Agency and the Department for Communities and Local Government, the Technology Strategy Board was able to provide grants of up to £150,000 to demonstrate innovative whole-house retrofit. Retrofit for the Future enabled over 500 organisations to take part in a whole-house retrofit project. The experiences gained are proving invaluable as the retrofit industry and supply chains continue to develop. Over 100 homes were retrofitted, mostly providing greatly improved living conditions and energy efficiency. Carbon emissions were reduced in many cases by between 50% and 80%, as reported in our previous 'Retrofit Revealed' publication. This and other information can be downloaded from the programme website: www.retrofitanalysis.org

This cost analysis is an important element of the legacy from Retrofit for the Future, and comes at a crucial time. There is unprecedented pressure from customers and regulators to scale up the delivery of energy-efficient retrofits in greater numbers, and budgets are under intense pressure. This creates growth opportunities for innovative businesses that can help deliver retrofit for a more affordable price. More affordable solutions are required throughout the supply chain. The industry can benefit by understanding the price points achieved in Retrofit for the Future.

The approach taken in Retrofit for the Future to driving innovation through collaborative projects was well received by industry. The learnings from Retrofit for the Future led on to the Scaling Up Retrofit competition, which challenged the industry to substantially reduce the price of retrofit whilst delivering 'assured performance'; so that customers achieve in practice the energy savings they pay for. The projects offered grants in the Scaling Up Retrofit competition are described at:
www.innovateuk.org/documents/1524978/1866952/Scaling%20Up%20Retro%20Fit%20of%20the%20Nations%20Homes%20-%20Results%20of%20Competition

Ian Meikle
Head of the Low Impact Building Innovation Platform, Technology Strategy Board

The Technology Strategy Board is all about driving innovation. We are the UK's innovation agency. We accelerate UK economic growth by stimulating and supporting business-led innovation.

1.0 Executive Summary

Sweett Group was commissioned by the Technology Strategy Board to analyse the set of cost data and information arising from the Retrofit for the Future programme. Retrofit for the Future enabled the retrofit of over 100 homes across the UK, with an ambition of achieving a reduction in primary energy consumption to 115 kWh/m^2/yr or less, and an 80% reduction in in-use carbon emissions.

This report presents the findings from the cost data analysis and provides a number of conclusions and recommendations. It covers:

- The average and range of costs of the retrofit interventions made by the project teams
- The factors that caused cost variations and opportunities to reduce these variations
- Actions that should be encouraged in retrofit projects (and what should be avoided), and
- Advice as to how to approach cost planning/ data management in retrofit projects.

1.1 Key findings

The table below sets out the average costs incurred for the various retrofit interventions. These costs are for the fully 'supplied and fitted' interventions.

Component	Specification*	Average cost (£/m^2)**
Windows	Double	£261
	Triple	£567
Internal wall insulation	Rigid	£123
	Natural	£368
	Hi-tech	£359
External wall insulation	Rigid	£161
	Natural	£150
Floor insulation	Rigid	£65
	Natural	£94
	Hi-tech	£130
Roof insulation	Rigid	£82
	Natural	£30
	Loose-fill	£14
Mechanical Ventilation with Heat Recovery (MVHR)	System + ancillary works	£6,117 per system
Low/ Zero Carbon (LZC) technologies	Air Source Heat Pump (ASHP)	£1,310 per kW
	Biomass	£1,742 per kW
	Ground Source Heat Pump (GSHP)	£2,893 per kW
	PV	£5,627 per kW$_p$
	Solar thermal	£1,739 per m^2

* *Explanation of each specification is provided in Section 4*

** *Where other units were used these are specified*

1.2 What factors caused cost variations, and what opportunities exist to reduce these variations?

Factors that caused cost variations were observed across the projects. These are set out in the table below, alongside the identified opportunities to reduce cost.

Factors causing a cost variation	Opportunities to reduce cost
• Using non-standard/ bespoke products can affect the expense of the product and the workforce (which may need to be trained accordingly)	• Where possible, use standard products that the workforce are familiar with and can install quickly and efficiently
• Procuring products from far afield (or immature supply chains)	• Source comparable products from suppliers closer to home
• The specification of the final finish/ product	• Do not over-specify: only specify what is required, rather than specifying top-of-the-range by default
• Systems/ products that are poorly designed and/ or installed result in remedial work being necessary, causing cost uplift.	• Take time to design and install systems/ products carefully from the outset to avoid the requirement for remedial work.

1.3 Delivering cost-effective retrofit projects

The following advice should be followed when considering a low-carbon retrofit:

Do	Don't
👍 Make sure that there is good communication between different aspects of the supply chain.	👎 Don't over-specify unnecessarily – if a conventional product works, it might be best to use it.
👍 Manage costs closely and in a systematic fashion (which can be easily replicated on other projects).	👎 Conversely to the above, don't always settle for the cheapest/ simplest solution without understanding the whole-life benefit/ impacts of its use.
👍 Take account of how novel products/ processes might affect the programme.	👎 Don't underestimate the difficulty of getting hold of novel products in small orders.
👍 Learn from the mistakes and successes of others so that these can be avoided/ repeated.	👎 Don't ignore the requirements of the end user.
👍 Make use of the financial (and other) support available.	
👍 Encourage learning and increase the awareness/ knowledge of your team/ supply chain.	

Contents

2.0 Introduction

The Technology Strategy Board is the UK's innovation agency. It is a business-led public body that promotes and supports research into, and development and exploitation of, technology and innovation for the benefit of UK business, in order to increase economic growth and improve quality of life. The Technology Strategy Board recently undertook a £17m programme called 'Retrofit for the Future'. This involved retrofitting over 100 domestic properties, to dramatically reduce their primary energy usage and in-use carbon emissions. The properties were addressed by a range of project teams comprising various construction professionals (e.g. contractors, architects, energy specialists and so forth). The project teams provided data on the cost of their retrofit works, which has informed this report.

2.1 Background

The UK government is committed to reducing net UK carbon emissions by 80% by 2050 (compared to 1990 levels). Buildings, particularly existing domestic buildings, are responsible for a large proportion of these carbon emissions; in the region of 27% of total UK emissions. Significant retrofit of existing domestic properties is essential. In response, the Technology Strategy Board implemented the Retrofit for the Future programme, to inspire and act as a catalyst for the retrofit market.

Launched in 2009, the Retrofit for the Future programme aimed to enhance understanding and awareness of the measures and technical solutions required to refurbish the existing housing stock to a high level of energy efficiency. Applicants were required to take a 'whole house' approach and establish an all-inclusive package of measures to cut energy use dramatically, and target an 80% reduction in carbon emissions. Retrofit for the Future was open to companies and organisations including housing providers and local authority housing stock holders. Projects were awarded up to £150k of funding to enact their proposed strategies and to demonstrate what could be achieved.

Retrofit for the Future was a business-led research programme, which explored whether an 80% reduction in carbon emissions from existing homes was technically possible using current design skills and supply chains. The Technology Strategy Board has subsequently launched a programme to drive down the cost of retrofit at scale, which will enable businesses to better meet the needs of their customers in the retrofit market.

2.2 About this analysis

The Retrofit for the Future project teams produced a final report, which explains the work undertaken in the properties and provides a summary of the associated costs. In some cases, additional background information on costs and specification was provided. Using this data, the aims of this cost analysis project were to:

- Analyse the costs presented by the project teams for their retrofit works, including:
  - The cost of implementing each retrofit measure
  - The average cost of each measure, and
  - The spread of the cost of each measure.
- Identify the factors that influence costs and could cause significant variance:
  - What a retrofit project team should aim to do and aim to avoid, and
  - How retrofit costs can be reduced.
- Recommend how cost data should be captured, managed and reduced:
  - Lessons learnt from the Retrofit for the Future projects, and
  - A template for structuring cost data on retrofit projects.

3.0 Methodology

A three-stage methodology was used to extract and analyse the cost information for each project and to develop the recommendations.

3.1 Stage 1 – Data structuring

Our analysis identified that project teams had adopted a variety of methods to structure and present their costs.[1] This was to be expected, since the teams were allowed to adopt their own approach to defining the costs of their projects.[2]

To enable analysis and comparison across the projects, a database and spreadsheet were developed to structure the cost data in a common format using the following headings:

Building data	**Specification data**	**Costs**
i. Property type	i. Component*	i. Cost per unit
ii. Build form	ii. Specification	ii. Materials
iii. Age band	iii. Description	iii. Labour
iv. Region	iv. Quantity	iv. Add-on
v. Footprint area	v. Unit	v. VAT
		vi. Total

** This was either: windows, internal walls, external walls, ground floor, roof, Mechanical Ventilation with Heat Recovery (MVHR) or Low/ Zero Carbon (LZC) technologies*

Retrofit practitioners need to undertake effective cost planning throughout the process. This requires the collection, review and management of cost data at each stage. To facilitate this process and to clarify what cost data is required, a model cost data template has been developed using the structure set out above. This model is provided in section 6.

3.2 Stage 2 – Data analysis

The following aspects were analysed for each major component of the retrofit works:

1. Description of the component and the type of products used by the project teams
2. Cost data
3. Factors leading to significant variance in cost, and
4. Opportunities to reduce costs of future retrofit projects.

3.3 Stage 3 – Retrofit cost-planning checklist

A cost-planning checklist has been developed, based on the reported experiences of the project teams and the cost analysis outlined in this report. The checklist is provided in section 5 for use by retrofit project teams as a cost-planning tool.

[1] *Due to the variability of how data was managed, not all projects could be drawn-on for this analysis. We have made use of cost data from 70 of the 100+ properties.*

[2] *The Technology Strategy Board did not originally intend to undertake a rigorous and detailed cost data analysis. This study has been commissioned subsequently, to identify trends in the data collected and to understand reasons for significant variance.*

4.0 Cost information for the major components

Cost data was extracted from each project report and grouped for each retrofit component. The data was plotted on a scatter plot, from which any extreme outlying data points were identified and removed if they could be explained (on the basis that they would unjustly affect the analysis[3]). A second plot was produced and used to analyse the data in more detail. This section presents the overall findings for each of the main retrofit components. In some instances sample sizes were small in number, hence the figures should be considered indicative and the related conclusions should be treated with a degree of caution. Sections 5 and 6 draw on this and provide information relating to how cost data can be more robustly managed/ maintained in future projects. Further information relating to the detailed analysis of the dataset is in Appendix A – Detailed data analysis.

Windows

Description

- Two thirds of projects installed triple-glazed units, with U-values of 0.7 - 0.8 W/m^{2}K.
- The other projects installed high-performance double-glazing units, with U-values as low as 1.1 W/m^{2}K.
- Three projects specified Passivhaus-certified units, to enable the Passivhaus standard to be achieved.
- Frames were either uPVC or timber.

Factors that caused cost variations

- There were three triple-glazed installations which cost significantly more than the other 18 triple-glazed installations. With two of the three, delays/ problems with suppliers were mentioned as reasons for high costs; the third used Passivhaus-certified units, which may have contributed to the higher cost.
- The most expensive units were vacuum glazing procured directly from the Japanese supplier. Specialist products procured from abroad generally had higher costs.
- Additional costs were incurred when windows were non-standard sizes, or when there was a large variation in sizes per order.
- One project proposed the replacement of window units without replacing the frame. In the event this was not carried out, as the team determined the associated cost and better performance of new windows to be a more effective option.

Opportunities to reduce costs

- The availability of triple-glazed products has increased significantly over recent years, and their cost has reduced accordingly.
- Use certified products when compliance with a particular standard is required.
- Take any opportunities to standardise window frame sizes, particularly if the property fabric is also being altered.

Retrofit for the Future reported costs (supplied + fitted) (£/m^2)

	Double-glazed	Triple-glazed
No. of installations (excluding outliers)	10	21
Average cost (£)	£261	£567

[3] This ensures that the dataset consists of 'reasonable' values only, i.e. those not significantly higher or lower than the central range of values. For more information about how outlying data was identified, please see Appendix A.

Internal wall insulation

Description

The products used for insulating internally were:

- Rigid insulation boards: EPS (expanded polystyrene), XPS (extruded polystyrene), PUR (polyurethane) or PIR (polyisocyanurate)
- Natural insulation boards: timber fibre or sheep's wool, and
- Hi-tech insulation: Aerogel or VIPs (Vacuum Insulated Panels).

Factors that caused cost variations

- The expense of hi-tech materials is largely reflective of them being specialist products (utilising cutting-edge technology) for specialist applications. They were typically used in situations where there was insufficient space for products of conventional thickness.
- In the majority of instances, internal insulation was installed with the residents remaining in the property. When a project involved temporary re-housing of occupants, additional costs of £3,000 - £5,000 were experienced.
- There was a variation in cost depending on how much labour was required for repositioning electrical sockets, skirting, coving and wall furniture.

Opportunities to reduce costs

- Coordinate work for when a property is vacant: e.g. whilst owners are on holiday, or between tenancies etc.
- Ideally, a single organisation should undertake both the insulation installation and remedial works (repositioning electrical sockets, skirting, coving and wall furniture). This will help to control costs as fewer trades are employed and time is used more efficiently.
- Contractors/ installers should be encouraged to take advantage of training opportunities to increase their skill levels with internal insulation, to compete in this growing market. Organisations such as the Construction Industry Training Board (CITB) provide information on training courses and construction skills.

Retrofit for the Future reported costs (supplied + fitted) (£/m^2)

	Rigid	Natural	Hi-tech
No. of installations	4	2	5
Average cost (£)	£123	£368	£359

External wall insulation

Description

The products used for insulating externally were:

- Rigid insulation boards:
  EPS (expanded polystyrene),
  XPS (extruded polystyrene),
  PUR (polyurethane) or
  PIR (polyisocyanurate), and
- Natural insulation boards: timber fibre or sheep's wool.

Factors that caused cost variations

- The type of cladding specified caused cost variations: complex finishes (i.e. those that require more regular maintenance/ replacement) added expense compared to cheaper, more conventional finishes. For example, one project specified a novel insulating render system, which proved to be more expensive than conventional systems as it required more time input from the contractor (i.e. learning how to mix and apply the product).
- Traditionally, external wall insulation was classed by planning authorities as an 'extension' (rather than 'permitted development', which it is now classified as). The 'extension' classification led to additional cost for some projects that had to submit multiple planning applications before permission was granted.

Opportunities to reduce costs

- Employing a knowledgeable architect/ builder who is familiar with local planning regulations will improve the likelihood of an application being approved without requiring resubmission(s). Despite 'permitted development' status being granted for external wall insulation, teams should still engage with local authorities to check their requirements.
- There are opportunities to reduce costs by employing contractors familiar with the products specified.
- Specialist external solid wall insulation installers are indicating that the cost is decreasing as experience is increasing.

Retrofit for the Future reported costs (supplied + fitted) (£/m^2)

	Rigid	Natural
No. of installations (excluding outliers)	12	2
Average cost (£)	£161	£150

Floor insulation

Description

The products used for floor insulation were:

- Rigid insulation boards: EPS (expanded polystyrene), XPS (extruded polystyrene), PUR (polyurethane) or PIR (polyisocyanurate)
- Natural insulation boards: timber fibre or sheep's wool, and
- Hi-tech insulation: Aerogel or VIPs (Vacuum Insulated Panels).

Factors that caused cost variations

- Floor insulation was installed either on top of, or below, the existing floor. The cost (and convenience) varied depending on whether it was applied to a suspended timber or solid concrete floor. Suspended timber floors were easier and cheaper to retrofit than solid concrete floors.
- Solid concrete floors were more expensive as they had to be either overlaid with expensive hi-tech insulation materials, or the concrete had to be broken up and reinstated with new rigid insulation below the screed.
- Hi-tech materials typically require more careful handling than conventional counterparts. For example, VIPs can be damaged and the vacuum broken, ruining the high thermal performance. If the workforce is not careful when installing them then expensive failures/ breakages may occur.
- Installing floor insulation is highly disruptive to the internal environment. Cost variations occurred between the options of moving tenants out or decanting room-by-room.
- In one occurrence, working around occupants led to an innovative solution to use foam-fill insulation under a suspended floor, to avoid the need to lift the floorboards. The consequence was the need to avoid the overheating of electrical wiring. The time spent identifying the wiring proved longer than expected and the approach proved to be less time-effective overall than lifting the floorboards.

Opportunities to reduce costs

- The expense of hi-tech materials means that waste is costly – reduce costs by reducing waste. Liaise with the insulation manufacturer who should be willing to assist on optimising the design to use the product most effectively.
- Be sure to treat expensive hi-tech materials with care, so that expensive failures/ breakages do not occur. To help prevent damage, store the materials in a safe location and leave the supplier's packaging intact until the material is required.

Retrofit for the Future reported costs (supplied + fitted) (£/m^2)

	Rigid	Natural	Hi-tech
No. of installations (excluding outliers)	9	1	7
Average cost (£)	£65	£94	£130

Roof insulation

Description

All projects installed roof insulation, except those that already had adequate insulation present.

The products used for roof insulation were:

- Rigid insulation boards: EPS (expanded polystyrene), XPS (extruded polystyrene), PUR (polyurethane) or PIR (polyisocyanurate)
- Natural insulation boards: timber fibre or sheep's wool, and
- Loose-fill insulation: mineral fibre quilt and cellulose fibre.

Factors that caused cost variations

- The roof is typically the least expensive part of a home to insulate, per square metre, as cheaper materials can be used and detailed finishing is usually not required.
- If the loft is to be used as a room in the roof, then finishing and (potentially) more expensive insulation materials are required (e.g. insulation must be fitted behind boarding in the depth of the rafter).
- A common contributor to cost variations was the associated labour, e.g. if multiple layers of insulation were specified, or if the shape of the roof was awkward for installation.

Opportunities to reduce costs

- If possible, use mineral wool batts laid over ceiling joists: this is a cheap material that is quick and easy to install, and requires no finishing (plasterboard, skimming etc).
- Most projects took the opportunity to install as much insulation as possible - going well beyond what building regulations require. This decision will have avoided the need for 'top-up' insulation to be added in the future, avoiding the extra cost of bringing back the labour.

Retrofit for the Future reported costs (supplied + fitted) (£/m^2)

	Rigid	Natural	Loose-fill
No. of installations (excluding outliers)	5	2	6
Average cost (£)	£82	£30	£14

Mechanical Ventilation with Heat Recovery (MVHR)

Description

- MVHR units are mechanical systems where cool, fresh outside air is drawn in to the building to replace warm, moist, stale air that is drawn out. The two airflows pass by each other in a heat exchanger and the heat transfers from the outgoing stale air to the incoming fresh air.
- 27 projects installed MVHR units. Six projects stated that the MVHR units were Passivhaus-certified.

Factors that caused cost variations

- There is a large variance in the cost data provided for MVHR systems. Where costs were significantly higher than the average/ expected costs it is assumed that these were instances where the nature/ layout of the property necessitated a more complex and difficult-to-install system.
- Passivhaus-certified MVHR systems were more expensive than non-certified systems.
- The cost of a system is influenced by the ease of installation. Instances where floor boards needed to be lifted for ductwork runs were typically more expensive.
- Some project managers stated that there was a lack of knowledge of technologies such as MVHR, and how they interact with other aspects of the retrofit. This compromised communication between different trades on site, resulting in a lack of coordination. Examples included not leaving enough space to install a unit, or assuming that ducting runs could be installed in areas where they could not (e.g. chimney voids). This resulted in increased costs through delays, redesigns and/ or remedial work.

Opportunities to reduce costs

- The contractor must have good communication with the MVHR system designer/ installer to ensure all parties fully understand the system design and installation requirements. This should help to avoid redesigns or remedial measures.
- Ensure the MVHR system is installed by an appropriately qualified tradesperson.
- A programme of toolbox talks would be beneficial to ensure that all affected trades are aware of the MVHR system installation, and understand what is required of everyone working near the unit and ductwork and how their actions could impact on the effectiveness of the system.

Retrofit for the Future reported costs (supplied + fitted) (£/m^2)

No. of installations	26*
Average cost (£)	£6,117**

**In one instance the cost of the MVHR system included monitoring equipment too. This cost could not be disaggregated into the different items hence the project has been removed from the dataset*

***Assumed that the cost is for the MVHR unit plus the ancillary works*

Low/ Zero Carbon (LZC) technologies

Description

- Various LZC technologies were specified on many projects.
- Photovoltaics (PV) and solar thermal domestic hot water systems were the most common.
- Other systems included air source heat pumps (ASHPs), ground source heat pumps (GSHPs) and biomass systems.

Factors that caused cost variations

- Two of the projects experienced a scenario where the system did not perform as anticipated. As a result, a temporary solution had to be provided (e.g. a gas boiler had to be fitted) and remedial work carried out to re-commission the system, which increased the overall cost.
- Poor scheduling of work resulted in unnecessary costs. For instance, installing scaffolding for insulating walls, then reinstating the scaffolding later to install PV.

Opportunities to reduce costs

- Combining the installation of LZC technology with other initiatives can lead to cost savings. For example, installing roof-mounted solar systems at the same time as fitting a new roof will mean that scaffolding will only be required once.
- The cost of PV has fallen from approximately £5,000/kWp in 2009 to around £1,700/kWp in September 2013 (based on a $4kW_p$ system). Products are readily available and there are an extensive number of skilled and certified labourers who have experience of installing PV.
- It is anticipated that the Renewable Heat Incentive (RHI) will help to drive the market for heat-producing technologies, leading to reduced costs. The anticipated learning rates[4] (e.g. the expected decrease in cost per annum) are 9% for heat pumps (both air and ground), 10% for solar thermal and 15% for biomass[5].

Retrofit for the Future reported costs (supplied + fitted)

	ASHP	Biomass	GSHP	PV	Solar thermal
No. of installations (excluding outliers)	3	2	1	13	22
Average cost (£)	£1,310/kW	£1,742/kW	£2,893/kW	£5,627/kW_p	£1,739/m^2

[4] *Learning rates are used to predict possible changes in the cost of LZC technologies as supply chains gain experience and capture increasing returns to scale in their production. The learning rate is defined as the percentage cost reduction achieved with each doubling of the cumulative number of units of the technology that have been produced.*
5 Source: DECC (multiple) – Redpoint / trilemma (2009), Element / Pöyry and Nera (2009), Sweett Group (2013)

5.0 Factors influencing the cost of a retrofit project

The review and analysis of the Retrofit for the Future cost data has enabled a number of themes on cost-effectiveness to be identified. These are set out in Figure 5.1.

Figure 5.1 Thematic factors that affect retrofit costs

Innovative products

- Intelligent selection
- Careful use
- Knowledge transfer/ shared learning
- Consult early with the local planning department

Workforce

- Familiarity with innovative solutions
- Training availability
- Clear responsibilities
- On-site coordination

Procurement

- Identification and selection of product
- Engagement and appointment of workforce
- Ensuring appropriate quantity/ minimising wastage
- Engagement with supplier/ manufacturer

Cost planning

- Comprehensive - providing sufficient data to enable cross-comparision future planning
- Manageable - collating data in a consistent format

Retrofit for the Future provides valuable insight into how and why cost variances can occur. A number of lessons have been learnt that the industry could benefit from adopting.

A key aspect of achieving cost-effective retrofit is through accurate cost planning. The following section contains a cost-planning checklist for use by retrofit project teams. Using the checklist at the earliest stages of a retrofit project is strongly encouraged.

The checklist includes:

- The likely causes of cost variations
- Success factors/ things to encourage, and
- Pitfalls/ things to be wary of.

Theme	How this can influence cost	Things to encourage ☺	Things to be wary of ☹
Innovative products	Particulars of property (e.g. space limitation or unconventional layout) necessitates a hi-tech solution	Consult with the manufacturer to ensure the most efficient use of material is achieved (for example manufacturers will have experience of the best way to lay/ fit their product and may offer design software to forecast the quantity of product required). Take extra care not to over-order and be aware of the minimum quantities that can be ordered.	Specialist and more expensive products should be used when the application deserves it. Understand the marginal payback of options (e.g. once a certain thermal performance has been attained the cost to increase it further can increase exponentially).
	Use of a novel product that is part of an immature market	Ensure a suitable lead-in time – if procuring innovative products give close attention to the delivery time, which can be longer than for conventional products. Engage with manufacturers to discuss 'trial opportunities'. Mutual benefits may be available e.g. the manufacturer discounts the cost in return for PR opportunities or ability to monitor the project as a case study. Engage with trade associations and other retrofit specialists/ advocates and learn from case studies and other examples of good practice. Provide occupants with an understanding of how products are designed to operate (and provide suitable handover notes/ guidance). This will avoid the need for future call-outs/ remediation works.	Do not be tempted to use a novel product without first taking time to understand its limitations. Do not try and address the most challenging requirements until you have first addressed the quick wins.
	Use of a particular system might require additional labour or works to facilitate it (e.g. installing internal insulation requiring sockets/ light fittings to be moved)	Liaise with the supplier to understand the labour requirements and factor this into the programme. Take time to carefully consider all the possible additional costs in the context of the particular building being retrofitted. Where additional work is required, try to organise existing contractors to undertake the work as part	Specialist contractors working with specialist products or systems might require more time than the project manager is accustomed to: this is likely to add to labour costs – ask contractors to provide their anticipated programme (and discuss/ agree key milestones).

Theme	How this can influence cost	Things to encourage ☺	Things to be wary of ☹
		of their existing duties. If a system has user-interface controls or maintenance access points, ensure these are located for ease of access once any other nearby building components are installed. Maintaining access for replacing MVHR air filters, for example.	
	Certain products require specialist tools/ equipment to enable installation. For instance, in one project, work was delayed due to the blade required to cut the product not being available at the required time	Ensure awareness of equipment associated with the product – ask the manufacturer up-front. Build in contingency for using novel products.	If products require dedicated tools then do not use unapproved alternative tools that could damage the product.
	Product has some form of certification which increases its price	If certification is not required, specify a like-for-like system without certification.	If there is an important reason for using a certified product (e.g. environmental assessment, client requirements) then do not cut costs on a non-certified alternative.
	Obtaining planning permission for novel retrofit works	Engage with the local authority at the earliest possible opportunity to understand their requirements and how this will influence the retrofit options possible. Identify where planning issues may arise. This is of particular relevance for external wall insulation.	Despite 'external wall insulation' now being recognised as permitted development (hence not requiring planning permission) there may still be barriers to address (e.g. conservation areas or inflexible planning authorities).
Workforce	Workforce tendering	When tendering for suppliers use the procurement process to identify the most effective/ experienced individuals with the retrofit scope of works. Engage with trade associations/ membership organisations such as the Solid Wall Insulation Guarantee Agency (SWIGA) and follow their recommendations.	Avoid organisations that do not have demonstrable experience (or at least be prepared to account for this in contingency). Whilst cost is a defining parameter, the lowest cost bidder is not always the most cost-effective choice.

Theme	How this can influence cost	Things to encourage ☺	Things to be wary of ☹
	Workforce unfamiliar with product	Appoint a specialist installer (follow the recommendations of the manufacturer). Try and find a contractor that has previous experience or has used a similar system. This will also reduce potential wastage where incorrect application needs to be corrected/ re-done. Hold toolbox talks to communicate any useful lessons learnt to colleagues/ subcontractors.	Do not allow the workforce to behave carelessly with innovative products that should be stored safely, to prevent damage/ theft until required.
Procurement	Procurement of products from abroad	If you procure from abroad, use established trade routes and suppliers. Similar products may be available within the UK, but from small-scale/ independent suppliers rather than large international suppliers.	Avoid procuring from sources that do not have a suitable reputation and credentials.
	Procurement of products with limited availability or long lead-in times	A contingency plan should always be prepared. Planning ahead by the project manager is essential to make sure the correct quantity of material arrives at the correct time. Be careful to order the correct amount at the outset to avoid having to reorder.	Some products have a very long lead-in time. Under-ordering can result in small additional orders which can delay programmes considerably.
	Use of financial incentives/ mechanisms	Make use of the mechanisms available to help finance retrofit works (e.g. Green Deal/ Energy Company Obligation [ECO]).	Understand the full process before committing to novel finance mechanisms (e.g. upfront costs of surveys which may not be recouped).
Cost planning	Management of cost data	Capture the cost data in a systematic fashion and provide sufficient data regarding product specification etc. This will enable data to be transferred across projects and will save time (through identifying which solutions work and which should be avoided on the next project). Use the cost data template provided in this report.	Reliance on old cost plans, or cost plans that were for less extensive retrofit works, will provide a false impression of the costs of undertaking a whole-house retrofit project.

6.0 How to develop a retrofit cost plan

There are a considerable number of retrofit programmes now underway within the UK. By learning from the programmes conducted by others, industry professionals will be better able to plan for a cost-effective retrofit. Clients and suppliers will also benefit from being able to compare the cost of the different solutions used across multiple retrofitted properties.

Capturing cost data in a consistent fashion is essential for enabling data from different projects to be compared. Consistency will help industry to understand project costs and keep them as low as possible, which will make it more affordable for clients to commission retrofit projects, creating business opportunities and jobs.

The recommendations below are on how to consistently record data in a retrofit cost plan.

1. Appoint/ engage with a cost professional in the early stages of the project (alternatively, identify who in the project team will have the responsibility for managing the early-stage cost data).

2. Use a standardised cost plan to set out costs and quantities. Initiate this early in the project. An example is provided on the next page.

3. When populating the cost plan, record: i) where the data is coming from, e.g. specification documents/ spreadsheets/ SAP (Standard Assessment Procedure) analysis, and; ii) from whom, e.g. architect/ engineer/ contractor. Recording the source of the data will be beneficial for later reference.

4. Provide as much explanatory information as possible with the cost data, e.g.: product obtained from supplier X; bulk discount obtained due to ordering >X no.; minimum quantity X number; typical delivery time X weeks/ months, etc.

5. Ensure that correct and consistent units are used. For example, it is more difficult to compare two PV systems if the data for one is in £/kWp and the other is in £/m^2.

6. Clearly disaggregate costs (e.g. materials/ equipment/ labour/ etc.).

7. Try to identify what 'additional costs' might arise (e.g. dealing with complicated dwellings or making good after the retrofit) and where they are more likely to arise (e.g. properties of a certain age and type). It is important to understand whether these costs are likely to occur across many properties or whether they are one-off costs unique to the project.

8. Label whether costs include/ exclude VAT and for which year the data was obtained.

6.1 Cost data template

A cost data template is provided on the next page. The template provides retrofit project teams with a structure to use as a starting point for managing their project's cost data.

Project reference:

Basic property data

Property type	
Build form	
Age band	
Footprint (m^2)	

Specification data

Component type	Identifier	Details/ specification	Quantity	Unit
Windows 1				
Doors 1				
External walls 1				
Floor 1				
Roof 1				
Mechanical 1				
Plumbing 1				
Electrical 1				
Low/ zero carbon technologies 1				
Internal works 1				
Prelims 1				
Other 1				

Notes

Identifier	= the general term for for the intervention
Specification	= the detailed description of the intervention
Quantity	= the amount
Unit	= e.g. m^2, m, nr etc.
Material	= material costs
Labour	= labour costs
Equipment	= hire / purchase of equipment in order to carry out work
Extras	= may include, for example, making good
VAT	= where possible, costs should be provided excluding VAT
Internal works	= e.g. internal partitions, stairs, finishes
Prelims	= e.g. management, design, welfare, OH&P. **Please specify and detail**
Other	= anything not covered by the above. **Please specify and detail**

This cost plan should be completed as per the headings above, so that costs are disaggregated sufficiently that analysis can be conducted.

Cost data

Component type	Material	Labour	Plant/ equipment	Extras	VAT included?	Total cost	Normalised cost	Benchmark cost	Notes
Windows 1						£			
Doors 1						£			
External walls 1						£			
Floor 1						£			
Roof 1						£			
Mechanical 1						£			
Plumbing 1						£			
Electrical 1						£			
Low/ zero carbon technologies 1						£			
Internal works 1						£			
Prelims 1						£			
Other 1						£			

Appendix A – Detailed data analysis

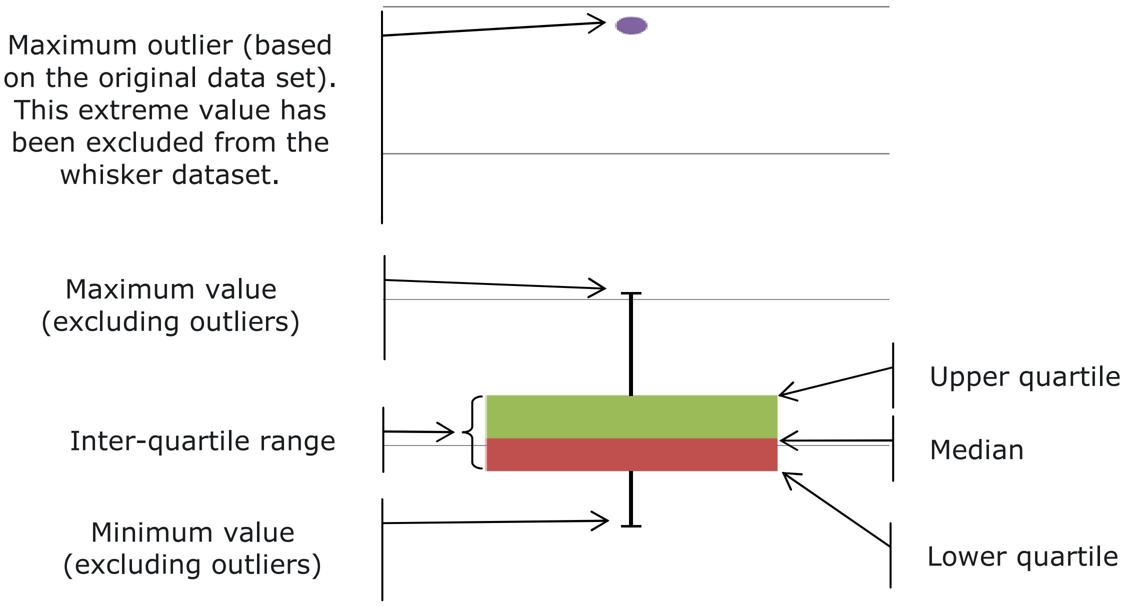
Cost data was extracted for each project and grouped for each building component (windows, internal wall insulation, etc). The data per component was plotted first on a scatter plot. The y-axis shows the cost per unit, and on the x-axis is the individual property reference as assigned by the Technology Strategy Board (i.e. "TSB xxx").

The scatter plots enabled any outlying data points that unreasonably skewed the dataset to be identified.[6] The outliers were usually caused by very specific circumstances, which have been drawn-on in our analysis and recommendations contained in this report. If the identified reason for the outlier was agreed to be abnormal then the data point was removed from the data set. A second plot – a box and whisker plot - was produced from the reduced data set, from which the costs of each component were determined.

The box and whisker plots demonstrate the spread of the dataset for each building component. The list below explains the statistical terms used in the analysis. Figure A demonstrates how these statistical terms are applied on a box and whisker plot.

- "The median". The data values are ordered from lowest to highest numerically. The median is the middle value of the ordered set of data. In instances where there is an even number of values, the median is the mid-point between the two middle values.
- "The upper quartile". The median splits the ordered data set into two parts. The upper part has its own median value, which is termed the upper quartile value.
- "The lower quartile". The lower part of the original split also has its own median value, which is termed the lower quartile value.
- "The inter-quartile range" (IQR). The IQR is the difference between the upper quartile value and the lower quartile value.

Figure A: How to read a box and whisker plot



[6] Suspected outliers were identified as any that were at least 1.5 x the inter-quartile range

Windows

Addressing windows was a common upgrade measure. Typically, triple glazing was utilised, with a specified U-value of 0.7 – 0.8 W/m^{2}K. This is in line with that required under the Passivhaus standard (which many projects used as a target).

Figure A.2: Scatter plot for windows (including outliers)

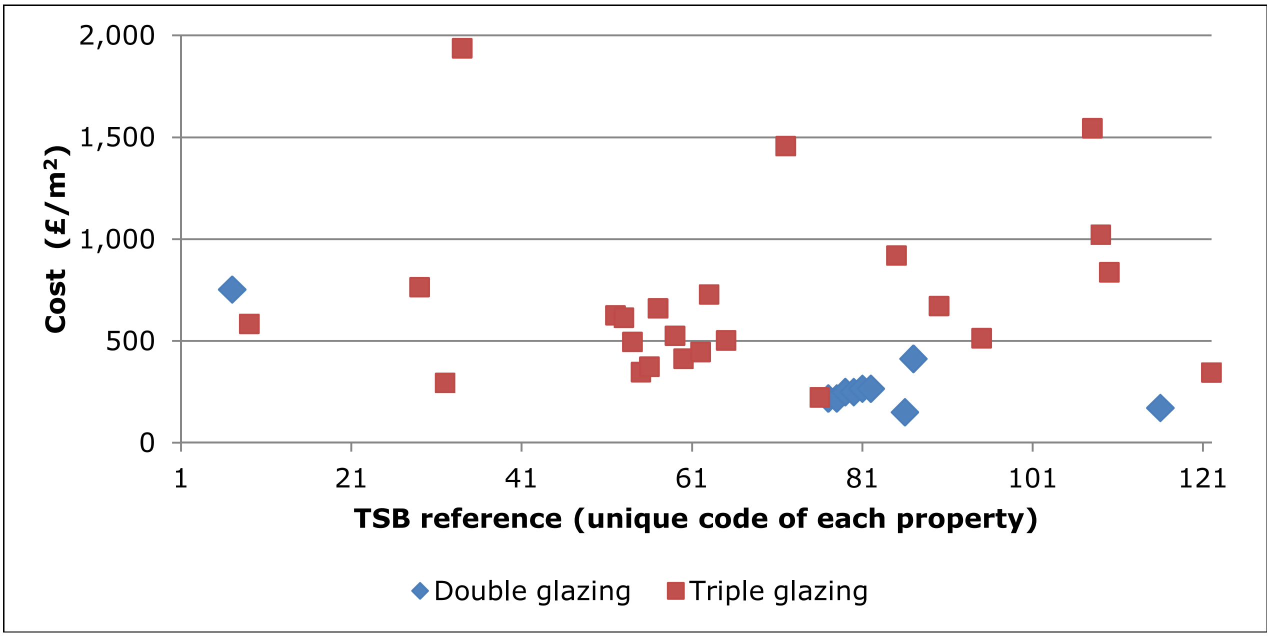


Figure A.3: Box and Whisker plot for windows

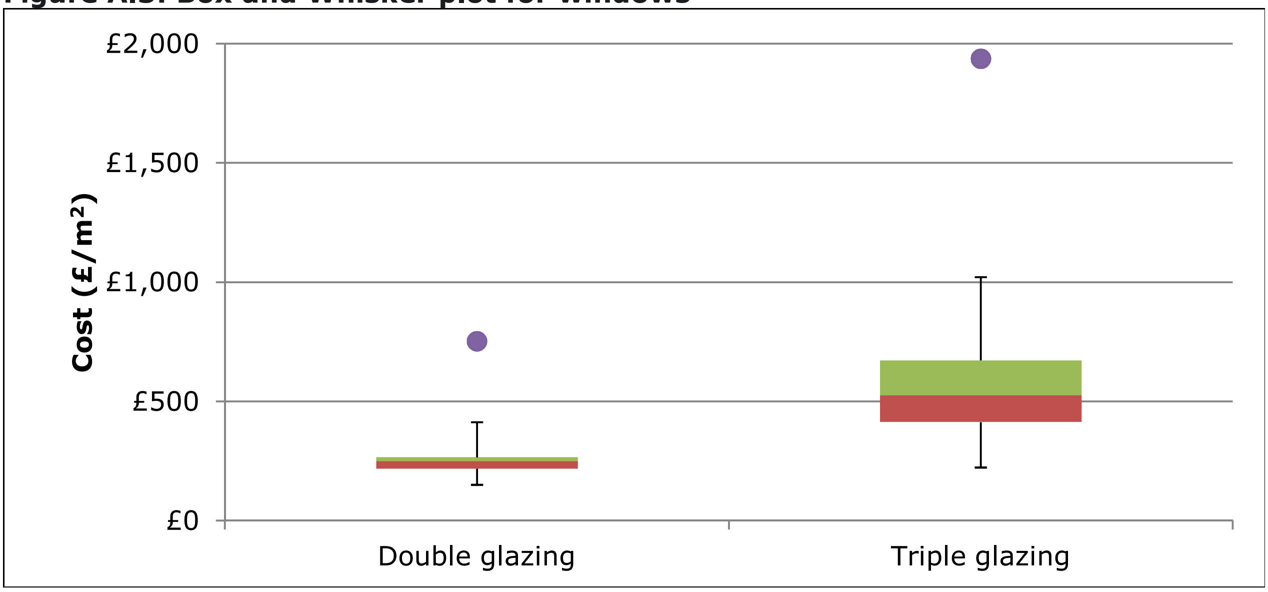


Figure A.4: Summary of cost data for windows (excluding outliers)

Product type	Count	Min (£/m^2)	Average (£/m^2)	Max (£/m^2)
Double	10	£150	£261	£413
Triple	21	£223	£567	£1,022

Internal Wall Insulation

The insulation materials applied were classified into four product types, namely: hi-tech/ multiple/ natural/ rigid.

Figure A.5: Scatter plot for internal wall insulation (including outliers)

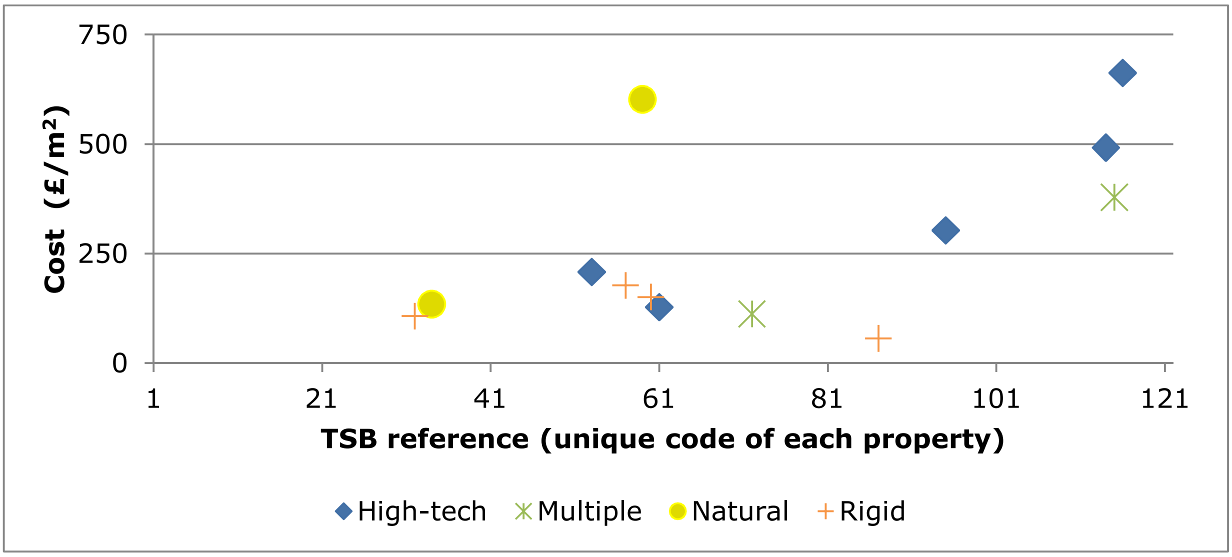


Figure A.6: Box and Whisker plot for internal wall insulation

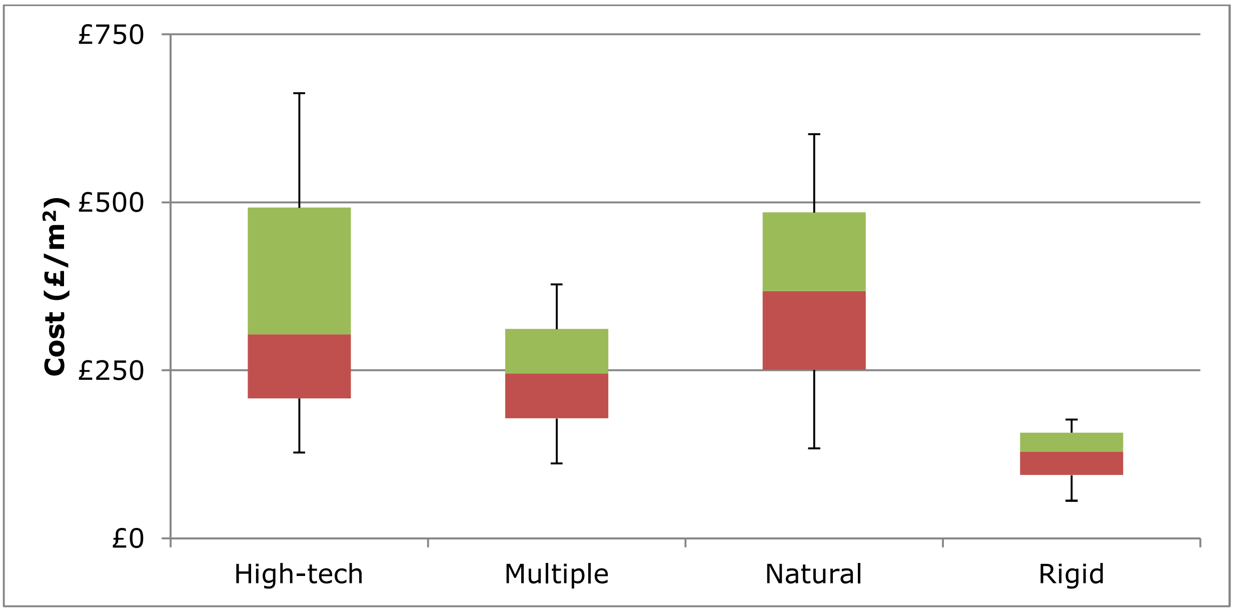


Figure A.7: Summary of cost data for internal wall insulation

Product type	Count	Min (£/m^2)	Average (£/m^2)	Max (£/m^2)
High-tech	5	£128	£359	£663
Multiple	2	£112	£245	£378
Natural	2	£134	£368	£602
Rigid	4	£56	£123	£177

External Wall Insulation

The insulation materials applied were classified into three product types, namely: multiple/ natural/ rigid.

Figure A.8: Scatter plot for external wall insulation (including outliers)

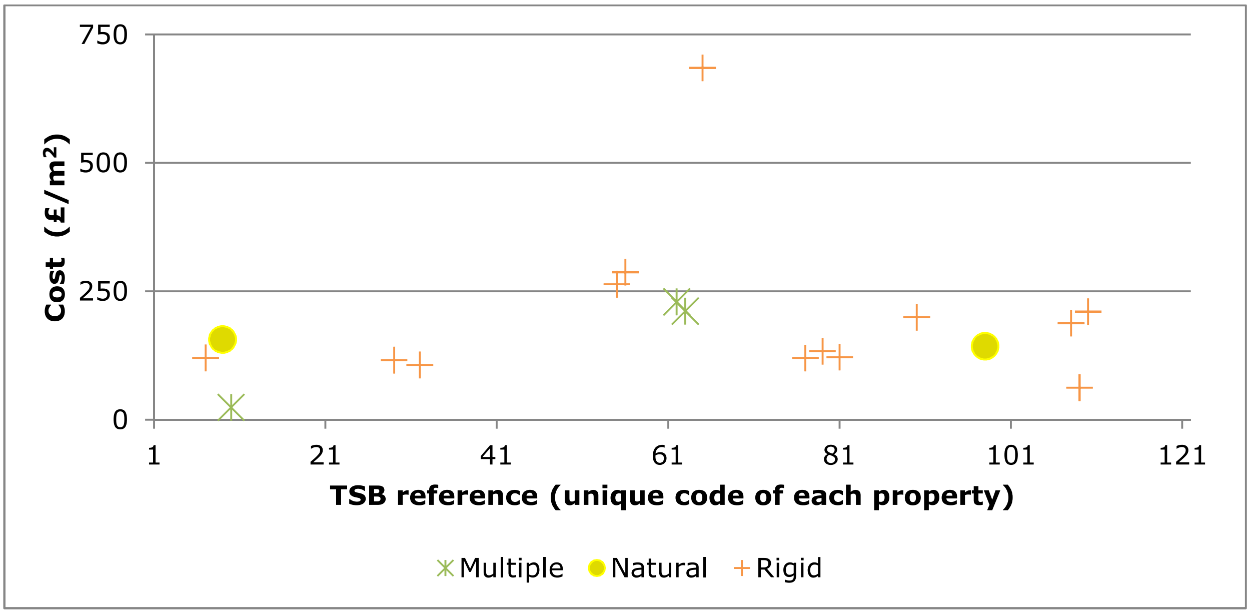


Figure A.9: Box and Whisker plot for external wall insulation

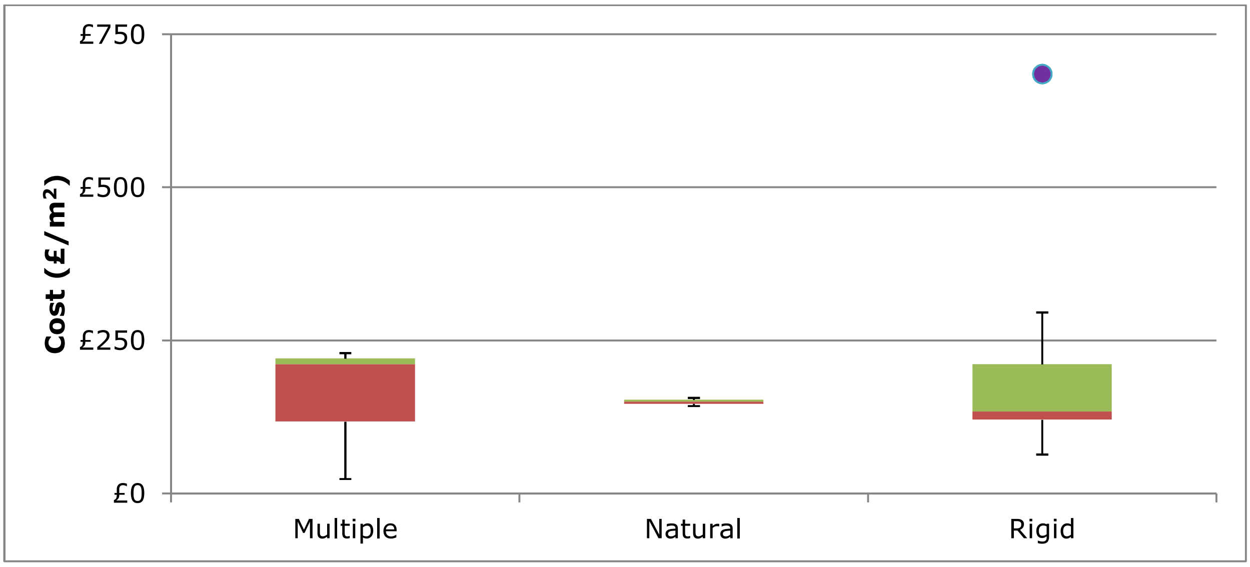


Figure A.10: Summary of cost data for external wall insulation (excluding outliers)

Product type	Count	Min (£/m^2)	Average (£/m^2)	Max (£/m^2)
Multiple	3	24	155	229
Natural	2	143	150	156
Rigid	12	63	161	288

Floor insulation

The insulation materials applied were classified into four product types, namely: hi-tech/ loose-fill/ natural/ rigid.

Figure A.11: Scatter plot for floor insulation (including outliers)

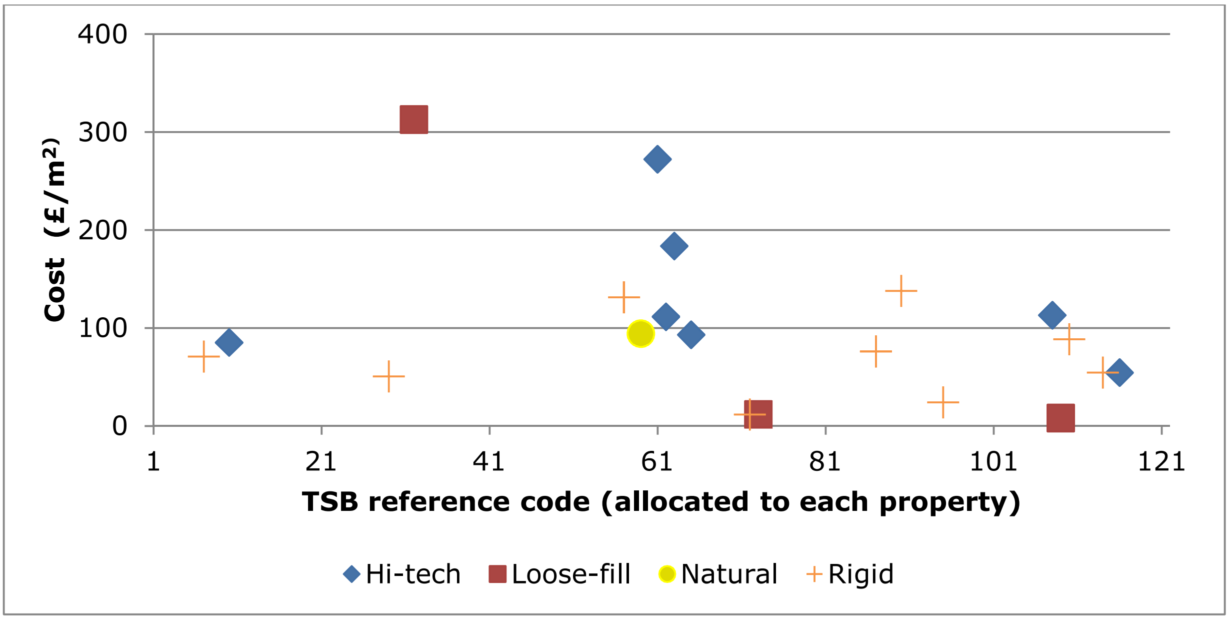


Figure A.12: Box and Whisker plot for floor insulation

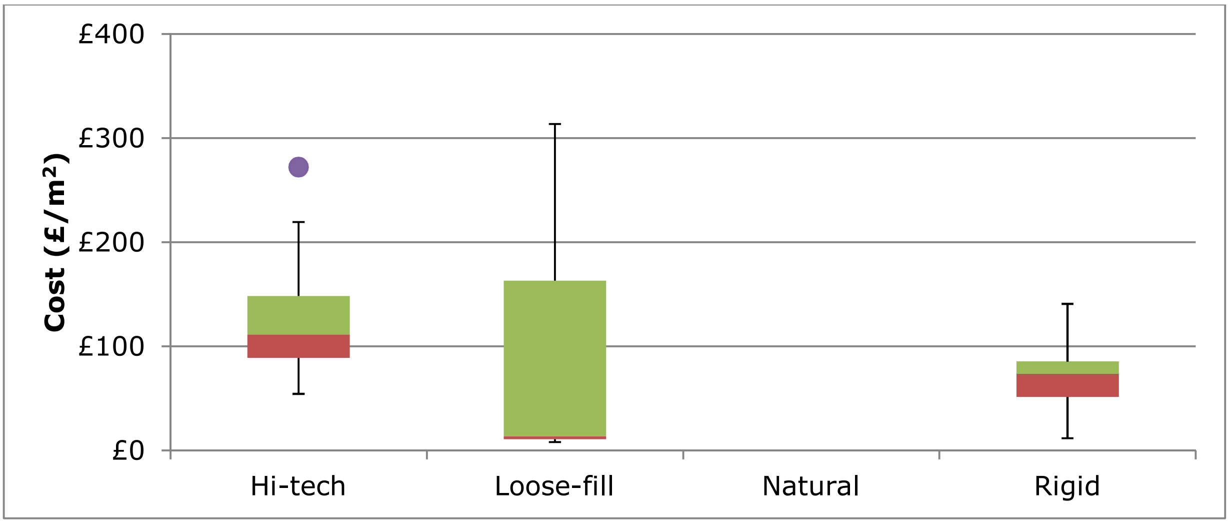


Figure A.13: Cost data summary for floor insulation (excluding outliers)

Product type	Count	Min (£/m^2)	Average (£/m^2)	Max (£/m^2)
High-tech	7	54	130	272
Loose-fill	3	8	111	313
Natural	1	94	94	94
Rigid	9	12	65	131

Roof insulation

The insulation materials applied were classified into four product types, namely: loose-fill/ multiple/ natural/ rigid.

Figure A.14: Scatter plot for roof insulation (including outliers)

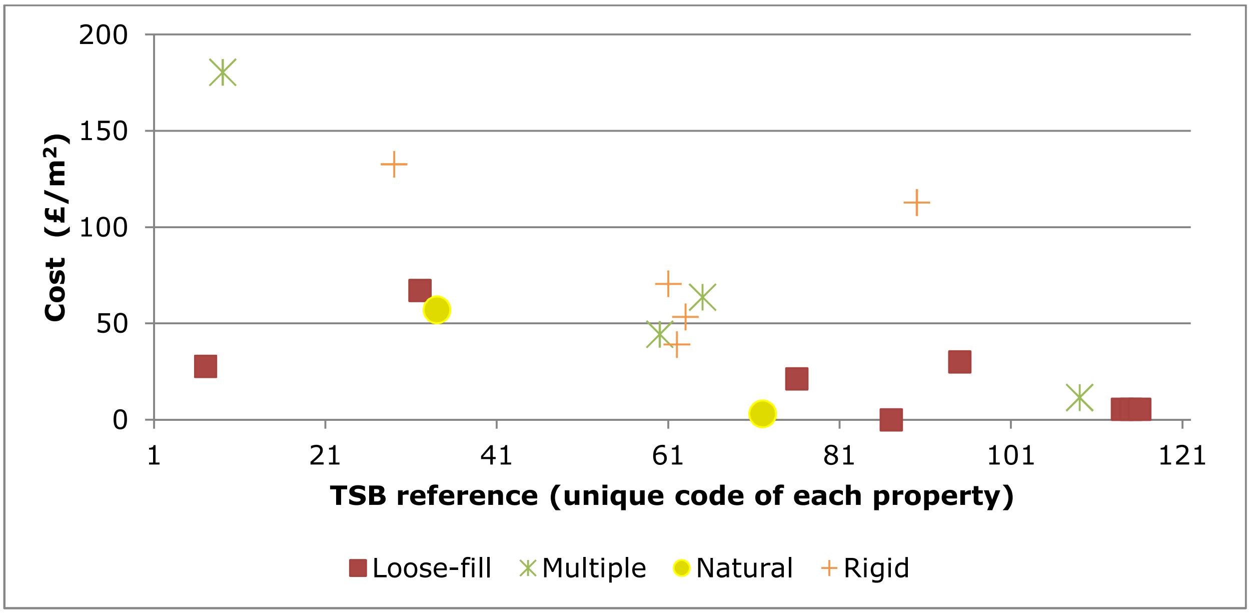


Figure A.15: Box and Whisker plot for roof insulation

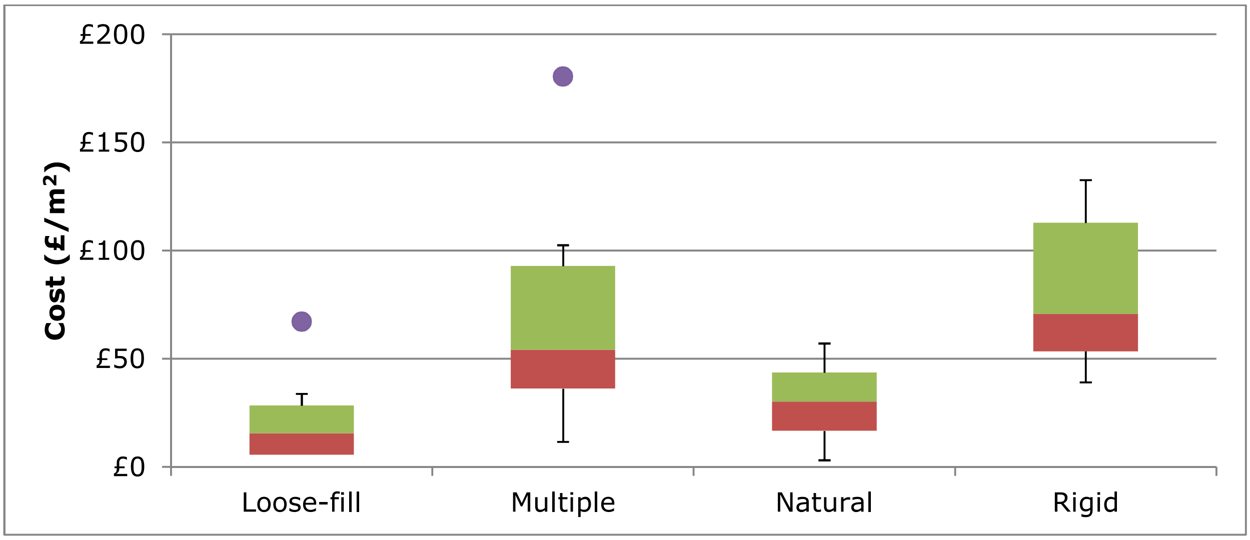


Figure A.16: Cost data summary for roof insulation (excluding outliers)

Product type	Count	Min (£/m^2)	Average (£/m^2)	Max (£/m^2)
Loose-fill	6	6	14	30
Multiple	3	12	39	64
Natural	2	38	30	57
Rigid	5	39	82	133

Mechanical Ventilation with Heat Recovery (MVHR)

MVHR units were typically specified where Passivhaus standards were targeted.

Figure A.17: Scatter plot for MVHR

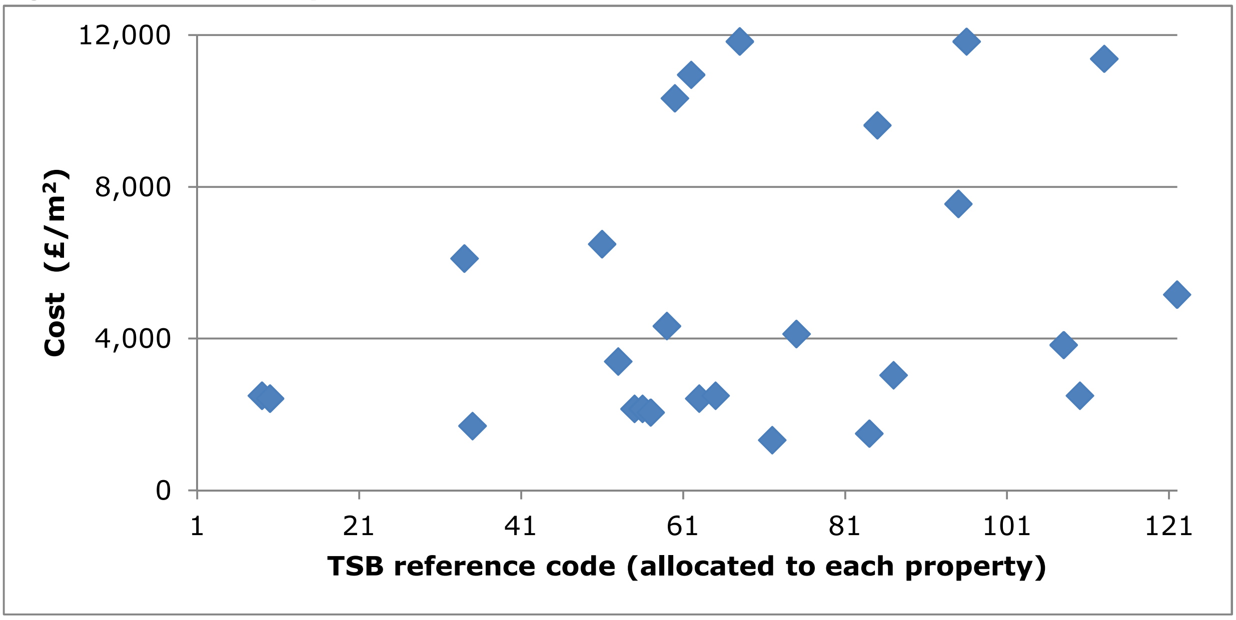


Figure A.18: Box and Whisker plot for MVHR

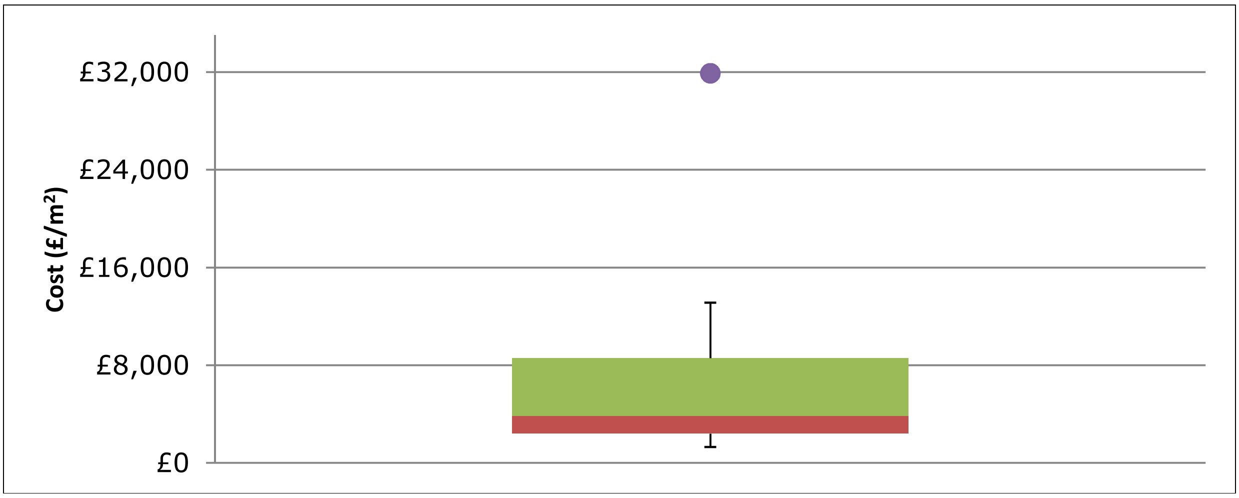


Figure A.19: Cost data summary for MVHR (excluding outlier)

Product type	Count	Min (£)	Average (£)	Max (£)
MVHR	26	1,326	6,117	11,836

Low or Zero Carbon technologies (LZCs)

The specified LZCs were: air source heat pumps (ASHPs)/ biomass/ ground source heat pumps (GSHPs)/ photovoltaics (PV)/ solar thermal.

Figure A.20: Scatter plot for LZC technologies (including outliers)

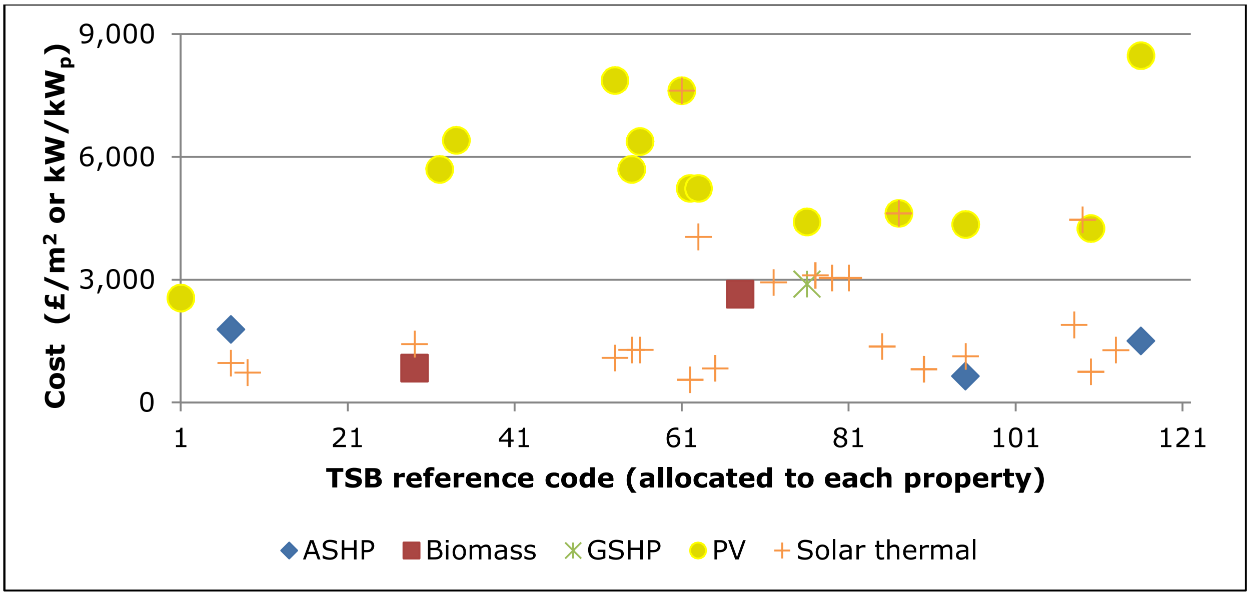


Figure A.21: Box and Whisker plot for LZC technologies

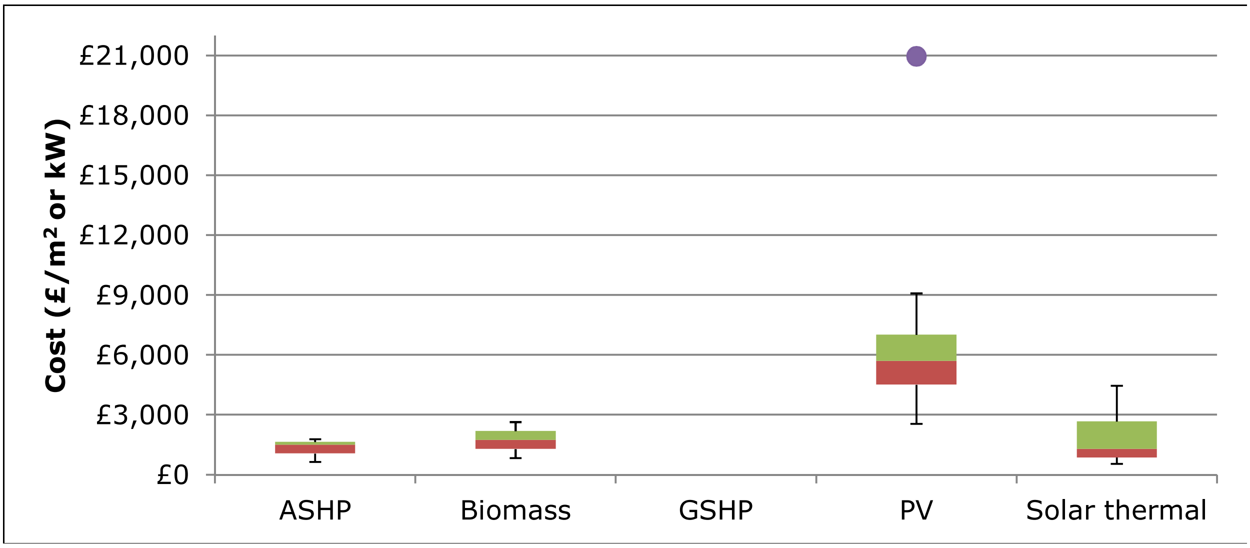


Figure A.22: Cost data summary for LZC technologies (excluding outliers)

Product type	Count	Min	Average	Max
ASHP	3	645 /kW	1,310 /kW	1,784 /kW
Biomass	2	839 /kW	1,742 /kW	2,645 /kW
GSHP	1	2,893 /kW	2,893 /kW	2,893 /kW
PV	14	2,551 /kW	5,627 /kW	8,475 /kW
Solar thermal	22	554 /m^2	1,739 /m^2	4,464 /m^2

Appendix B – Detailed methodology

The applied methodology was split into three stages:

- Stage 1 – Data collation, review and refinement
- Stage 2 – Cost data analysis
- Stage 3 – Appraisal of data and reporting.

Each stage is explained in further detail over the following pages.

Stage 1 – Data collation, review and refinement

Data review and disaggregation

All information was transferred from each final report into a single repository i.e. a cost-and-analysis database. The structure of the database enables effective cross-comparison of the data. It was informed by Sweett Group's cost consultants who provided a model structure, which replicates the cost plan that an experienced cost consultant would use for initial cost projections for a domestic retrofit project. The data for each case study was broken down into the following areas:

Building data

i. Property type
ii. Build form
iii. Age band
iv. Region
v. Footprint area

Specification data

i. Component*
ii. Specification
iii. Description
iv. Quantity
v. Unit

Costs

i. Cost per unit
ii. Materials
iii. Labour
iv. Add-on
v. VAT
vi. Total

** This represents the individual building components that were addressed through the upgrade process, namely: windows, doors, internal walls, external walls, ground floor, roof, mechanical, plumbing, electrical, Low/ Zero Carbon technologies.*

Gap analysis

After populating the database, a gap analysis was undertaken to identify any missing data that would prevent detailed analysis. Sweett Group agreed with the Technology Strategy Board's suggestions for solutions that would be deployed to populate the missing data.

There was significant variance in the level of detail on cost data provided by the different project teams. Some of the projects had detailed cost data with supporting information as to how the overall cost could be disaggregated, whilst other projects were less detailed. The typical gaps and what was done to account for them are set out below:

Table B.1: Summary of principal gaps in case study data

Item	Gap	Source of data
Building data	• Fundamental information missing, such as building type.	• Review of SAP data sheet allowed relevant building data to be obtained.
Specification	• Dimensional data (e.g. area of windows) missing.	• Review of SAP data sheets. • Review of drawings for the property.

Item	Gap	Source of data
data		• Use of BRE standard house type data*.
	• Capacity/ area of LZC technology missing.	• Capacity assumed based on the size of the dwelling and/ or output data stated within SAP datasheet.
	• Thickness of insulation not provided.	• Obtain U-value (the measure of heat transfer) from SAP datasheet and use U-value calculator to determine the thickness of product required to deliver the U-value specified.
Costs	• Costs for specific components not provided.	• Review alternative sources of Retrofit for the Future data; e.g. Residential Retrofit book (a collection of 20 case studies). • Focus on the components for which data was provided.
	• Costs not disaggregated (e.g. single cost provided for a number of components, for example a cost for 'building services' may be provided but this would cover a number of different products).	• For some case studies it was not possible to disaggregate data, hence these case studies did not appear in the final analysis. • In some scenarios specific components within the case study did have useful data, hence this was utilised where possible.
** The BRE standard house types provide data for 'average' or 'typical' house types (e.g. 3-bed semi-detached, 2-bed apartment, etc) and genres (Victorian, Georgian, post-war, etc).*		

Stage 2 – Cost data analysis

Identification of benchmarks

Each component was grouped into common product types, and the benchmarks represented what the 'typical' cost of the component should be. Benchmark costs for each product were determined by Sweett Group's cost consultants; equipment, installation and other costs (such as overheads and profit) were included. These costs were obtained through a range of measures including:

- Use of data from previous/ current residential projects
- Use of price books (such as SPONS)
- Direct engagement with product suppliers and/ or manufacturers.

All prices were determined as 2013 equivalent. The components were grouped as outlined below:

Table B.2: Summary of component/ product type classification

Component	Product type	Further explanation (where required)
Windows	Double	-

Component	Product type	Further explanation (where required)
	Triple	-
Internal/ external/ floor/ roof insulation	Hi-tech	Novel/ innovative products such as aerogels or VIPs
	Loose-fill	Such as mineral wool
	Natural	Such as sheep's wool
	Multiple	Scenario where a combination of product types have been included
	Rigid	Foam-based products such as expanded polystyrene (EPS)
Mechanical ventilation with heat recovery (MVHR)	MVHR fan unit(s) and associated ductwork	-
Monitoring	Monitoring	Projects were required to install energy and environmental monitoring systems, which wouldn't be installed in a conventional retrofit
LZC technology	Air source heat pumps (ASHP)	-
	Biomass	Includes wood-burning stoves
	Ground source heat pumps (GSHP)	-
	Photovoltaics (PV)	-
	Solar thermal	-

Normalisation of cost data

The costs for each component were normalised to enable comparison across all of the case study data (and against the benchmarks). Costs were normalised as follows:

- Windows — £/ m^2
- Internal/ external/ floor/ roof insulation — £/ m^2
- Solar thermal — £/ m^2
- MVHR — £/ system
- ASHP/ GSHP / biomass — £/ kW
- PV — £/ kW_p

Comparison of data

To compare the data gathered, 'scatter' and 'box and whisker' plots were created for each of the product/ construction types. The scatter plots enable a review of the correlation of the data. The box and whisker plots enable evaluation of the range of costs for the product/ component in question.

Stage 3 – Appraisal of data and reporting

For each component the following data was captured:

Commentary:	Description of the component and the product types used.
Key observations:	Appraisal of cost correlations and comparison against benchmark data.
Lessons learnt/ recommendations:	Where outlying points were identified, the reasons behind this were investigated. In many cases there was evidence to explain why the costs were substantially higher/ lower than the average and/ or benchmark data. Recommendations could be determined from these findings as to how to avoid (or replicate) these costs.
Learning/ future cost forecasts:	Commentary was provided relating to how costs had changed in recent years and how they were forecast to change.

Development of data capture template

As part of this project, a model template has been developed. Use of the template would facilitate the collation of data in future exercises, by making it clearer to retrofit practitioners what cost data should be collected.

The model template has been informed by Sweett Group's cost consultants and follows accredited cost planning guidelines. It can be found in section 6.

Africa
Americas
Asia
Australia
Europe
Middle East

www.sweettgroup.com

T14/029 January 2014