Programme Area: Buildings

Project: Building Supply Chain for Mass Refurbishment of Houses

Title: Draft supply chain scenarios

Abstract:

Please note this report was produced in 2011/2012 and its contents may be out of date. This deliverable is number 3 of 8 in Work Package 4. The report reveals the results of a detailed evaluation of supply chain processes (survey, installation and through life) and develops hypotheses for the systems and commercial structures, which could deliver whole house refurbishment on a mass scale. The evaluation methodology is presented and a preferred supply chain model identified. The conclusions presented within this deliverable will be tested and refined with stakeholders from across industry and government. The updated hypotheses will then provide the foundation for a comprehensive change management plan to be developed in subsequent deliverables.

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.

Energy Zone Consortium

Optimising Thermal Efficiency of Existing Housing

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Draft Supply Chain scenarios

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1. Executive summary

This report reveals the results of a detailed evaluation of supply chain processes (survey, installation and through life) and develops hypotheses for the systems and commercial structures, which could deliver whole house refurbishment on a mass scale. The evaluation methodology is presented and a preferred supply chain model identified. The conclusions presented here will be tested and refined with stakeholders from across industry and government. The updated hypotheses will then provide the foundation for a comprehensive change management plan for subsequent phases of the project.

Future supply chain scenarios were developed, and existing models assessed, in a structured stakeholder engagement programme. A series of focused workshops, involving targeted industry players, formed the core of the programme. This commenced with a qualitative comparison of UK retrofit with that undertaken in Europe. Failure mode analysis revealed consistent limitations, intrinsic to the UK supply chain, including poorly integrated processes throughout, no standardisation, excessive duplication & re-work, multiple surveys and inertia in the development of innovative products.

Future supply chain structures were then assessed through the next phase of workshops. A systematic gap analysis was undertaken, which revealed six primary impediments to creating a workable supply chain model. The elements were grouped into survey, skills, training & accreditation, legislation & regulation, programming and products & processes.

These elements were considered to be impediments in each of the supply chain options. By addressing these impediments through the change management plan a **scalable unit model** is considered to offer the greatest potential for delivering the customer value proposition and meeting the technical & financial challenges of mass roll-out. The methodology used to evaluate each option comprises a set of standardised assessment criteria i.e. functionality, flexibility, dependability, speed, cost, disruption, trust.

The report also presents a range of costed retrofit solutions developed with stakeholders during the final workshop and subsequent detailed data analysis. A measure-by-measure base case is evaluated against packaged approaches for both external and internal wall insulation. These packages are sub-divided into logical service offers (bronze, silver, gold) designed to meet the minimum value proposition, with customer value-added options.

A cost benefit analysis revealed excessive payback periods for all of the packages at current prices. Using the predicted eroded costs, payback decreases, from around 30, to less than 20 years; still longer than desirable. In parallel, work package 3 has been developing new technical solutions which have yet to be evaluated. With further iterations of the design and cost review an acceptable target cost and payback will be achieved. A key feature will be the integration of a systems engineered detailed design with a robust installation strategy as part of the next deliverable 4.3.

Finally, the report summarises the next phase of work required to realise the preferred option, highlighting key areas of work to ensure the supply chain is configured appropriately. In addition to impediments discussed above, further work is needed on solutions for product consolidation and supplier collaboration. A more fundamental issue however, revealed in this phase of work, is the functional separation of competencies and training; simplification and ‘right-sizing’ the scope for retrofit is essential if mass roll-out is to be achieved.

2. Background and link to other work packages

Buildings are responsible for 40-50% of the national primary energy consumption in the UK, half of which is used in domestic buildings for lighting, heating and cooling. More than 85% of the UK's housing stock in 2050 will be dwellings already built today. Only a fraction of 1% of which have been proven to have adequate thermal performance to meet the UK's energy targets. To meet the UK's commitment of reducing CO2 emissions by 80% from 1990 levels energy demand for domestic use must be reduced. The Energy Zone Consortium Project is focussed on reducing domestic energy consumption through increasing thermal efficiency of domestic properties. The project is divided into 6 work packages:

Work Package 1 -Understanding thermal performance of the housing stock at an individual dwelling level.

Work Package 2 - Impact of thermal efficiency measures on the UK housing stock.

Work Package 3 - Developing retrofit solutions to improve thermal performance of our national housing stock.

Work package 4 - Developing a sustainable supply chain to deliver whole house retrofit on a national scale.

Work Package 5 - Understanding customer value & maximise the take up of retrofit.

Work Package 6 - Developing the policy and regulatory framework to manage, support and encourage whole house retrofit.

This report presents a range of supply chain scenarios to meet the needs of a national whole house retrofit programme.

3. Approach

The objective of Deliverable 4.2 is to develop refurbishment supply chain options for the delivery of whole house retrofit to the mass market. The approach taken was to use input from the technical intervention (3.3), draft supply chain design (4.1) and Customer requirements work packages (5.2) to develop target retrofit systems with different options for delivery. The focus is on the delivery mechanism and process requirements of the three phases of retrofit identified during work package 4.1

A workshop programme was used to create process designs for the three phases of retrofit - Survey, Installation and Through Life. A **F**ailure **M**ode and **E**ffect **A**nalysis (FMEA) was carried out on the survey and installation processes, the results from these will be used to prioritise improvement / development activities in collaboration with the construction industry. The approach is illustrated below in figure 1

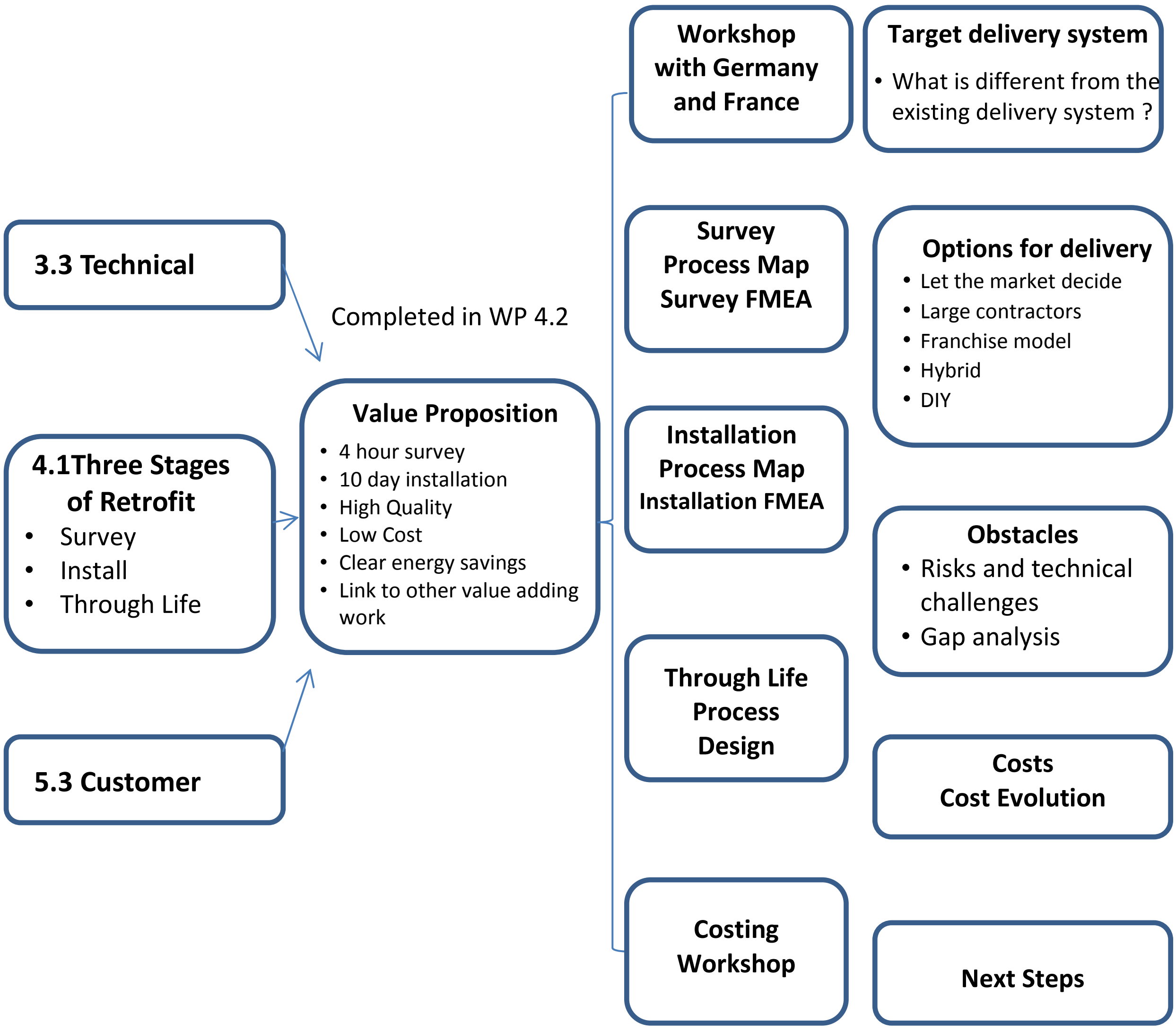


Figure 1 Approach to Work Package 4.2.

3.1 Method

A series of workshops were planned involving supply chain stakeholders and representatives of other relevant work packages, the sequence of these was.

1. Positioning workshop with representatives from France and Germany.
2. Survey Process FMEA.
3. Installation process FMEA.
4. Through Life process mapping and design.
5. Survey process mapping and design.
6. Installation process mapping and design.
7. Retrofit costing and cost erosion over time.

3.2 Workshop Process

To gain insight into the current retrofit industry, a targeted range of people were invited to participate in a series of one day workshops. The relevant process steps were analysed to understand in detail what is needed to undertake a whole house retrofit and where problems and difficulties occur. At all times a *systems level* approach was taken to ensure a total engineered solution is ultimately achieved.

The sequence of workshops was planned to deliver an understanding of the landscape of whole house retrofit with input from representatives of the industry from Germany and France where retrofit is more frequently carried out than in the UK. With this insight the current processes employed for retrofitting existing properties in the UK were examined in detail and subjected to an FMEA. This was carried out for both the survey and installation processes. Results from these workshops are included as appendix 4

The purpose of the FMEA was to understand which areas of retrofit activity are the most vulnerable to poor quality, repeatability, performance and customer acceptance. Each activity was scored in terms of:

- The likely failure mode and Severity of the failure at each process stage (what goes wrong).
- The likely frequency of the failure (how often does it go wrong).
- The detectability of the failure (if you can find out if it's gone wrong before you leave site).

In addition an assessment was made of:

- The difficulty of each process step.
- The impact to the client.
- Whether the work at the process step (or part of it) could be externalised (completed without involving access to the home ore householder).

After the above was completed, a follow on workshop was held where the through life process was designed and mapped, the scope of this covered handover from the retrofit installer to the householder through on-going maintenance, service and upgrade to disposal at the end of useful life. This covered to two value proposition alternatives of **Fit and Forget** and **Service Contract** developed in the 4.1 report.

The most involved processes were mapped in two consecutive workshops, and covered the survey process first and followed by the installation process.

The final workshop covered retrofit costs and how these may be eroded over time, again this involved current players in the retrofit supply chain. The presentation materials and attendance lists for these workshops are included in appendix 5

3.3 Workshop distilled outputs

3.3.1 Workshop outputs – FMEA

During the FMEA workshop each process step was studied and failure modes listed. The effects of these failures were rated in terms of severity, frequency and detect ability. The highest scoring steps will be treated as priorities for improvement as this project progresses, the majority of items scoring high Risk Priority Numbers (RPN) (RPN =Severity score X Frequency score X Detectability score). These relate directly to the risks associated with the task, and the consequences of incorrect judgement or poor workmanship, materials or methods.

The stakeholders formed a view of how much tasks could be externalised (completed prior to arrival at the property) and colour-coded each Green, Yellow or Red with increasing difficulty to complete off-line. This information will be used in the design of the future state survey process. The idea is to collect as much data about a property prior to visiting it; decreasing the amount of time taken on site involving the householder. With the target being a whole house Survey in 4 hours or less.

Example of a completed FMEA Ticket

Category	External Walls	Item #	1		
Prepare site					
Method	Scaffolding up, pavement up, garden impact	EXT	CRIT	Imp	Add
Scaffolding erection area prepared			H	M	L
Scaffolding primary		Dis		X	
Cherry picker		Time			X
		Risk			C
Improvement	Mobile scaffolding but this has H&S impact	£		X	
		Severe	Freq	Detect	RPN
		9/2	2/3	2/2	36/24
Classification	L/L				

The Failure Mode Effect Analysis revealed the following key themes:

- The need to treat retrofit measures as a system in order to maximise energy saved and minimise consequences through improved interfaces between solutions.
- It is challenging to determine some aspects of a property (without intrusive works) such as:
  - Condition (damp, floor joists, DPC, rafters, cavity wall ties)
  - Contamination (Asbestos, Radon, mould growth, dry rot etc.)
  - Existing building status (cavity fill, existing U values, cold bridging)

- The robustness of the interfaces between measures and between process steps are vital to reduce and manage risk. Standard work will be crucial to reduce risk and increase quality.
- Duplication of effort is avoidable during retrofit. Current delivery systems are split by trade and product silo; resulting in overlap and duplication during both the survey and installation processes. This increases the number of times a task is handed off to another resulting in increased error rates.
- Many steps of both the survey and retrofit had a high RPN score meaning they are not robust. These steps will need to be improved, particularly if the survey is carried out by an organisation separate from that carrying out the retrofit work.
- When installing retrofit measures key areas for improvement are to:
    - Avoid repeat (eg. lifting floorboards) and duplication of work.
    - Avoid having to make good (this is rework!).
    - Avoid damp and mould problems.
    - Improve solutions to cold bridging (linked to above).
    - Improve methods / equipment for working at height.

Improve insulation systems so they clip together needing little or no finishing processes.

Methodologies

To realise improvements in areas listed above, two distinct approaches will be needed. A Left to right approach eliminates waste in existing processes whereas Right to Left is a potent method to develop innovative solutions without the constraints of current paradigms.

Methods to be used in process design and development focus on lean tools which are extensively used in manufacturing industry:

- Waste Elimination (Elimination of the classic 7 wastes – Transport, Inventory, Motion, Waiting, Overproduction, Over processing, defects)
- Quality first / Zero Defects
- Just in time manufacturing
- Changeover Reduction (SMED)
- Jidoka (operator focussed automation)
- Poke Yoke (Error Proofing)
- Eliminate, Simplify, Combine

3.4 Obstacles objections and opportunities

3.4.1 Common themes

Common themes from the process mapping and FMEA workshops were

- Risk management is important, particularly at the interfaces between survey and installation, and between measures installed. This is particularly important if costs are to be contained.
- A **Whole Systems** approach is needed to avoid unintended consequences (condensation, rotting timbers, damp, mould etc.) and provide robust solutions.
- Duplication of effort can be avoided through understanding and deploying the right teams with the right competences. These are unlikely to sit comfortably within the existing trade boundaries and qualification / accreditation systems.
- Education of the public on the advantages / disadvantages and benefits of different measures is important, as is an understanding the motivations behind retrofitting the home and barriers to this.
- Trust in the company or person contracted to carry out the retrofit work is paramount and cannot be overstated.

3.4.2 Enabling innovation

With the benefit of a process map for each of the retrofit stages, several opportunities to improve quality and decrease risk and cost were revealed:

- To Gather Data:
  - Required for future repair, maintenance and upgrade.
  - Required for EPC rating.
  - Required for energy modelling.
  - Up front data that can be collated prior to visiting the property to reduce time spent on site.
  - That can be shared with government and infrastructure suppliers to assist in energy supply planning and optimisation.
- Tools and equipment:
  - Glass ‘low-e’ coating detectors combined with moisture meter and other functionality.
  - Laser scanning and measurement systems (whole room, face of house).
  - Cavity wall condition / fill status.
  - Cavity wall tie condition monitor.
  - Floor joist condition monitor.
  - Simple – non-invasive air leakage test – able to test room by room.
  - Simple and fool proof heat leakage test.

- Test for cold bridging.
- Simple and quick systems of work for working at height.
- Clip together or clip into bracket wall insulation system.

At this point in our research these are not considered to be pre-requisites for successful mass retrofit. However as part of the workshop to be held during Work Package 4.4 these will be ranked in terms of potential to improve retrofit process and results.

4. Outputs from mapping process

4.1 Survey Process

The survey process for whole house retrofit is complex and potentially time consuming. There are many areas where pre-existing conditions could increase the work needed during retrofit to correct problems adding time and cost to the process. To guard against this a robust survey is needed. The requirements for instrumentation and methods to improve process robustness were highlighted during the workshops and are listed in 3.4.2 and 5.7.

In the future a survey meeting the required value proposition time of 4 hours or less can be envisaged, however the following will need to be in place.

- Effective processes / methods to collect accurate information about the property type, history and occupancy prior to visiting
- Methods and equipment to allow accurate measurements to be taken, for example, room sizes, wall size and profile, window aperture sizes etc.
- Methods and equipment for assessment of the property condition for example, bay window lintel and floor joist condition.

A key question is whether the survey could be carried out by a specialist who is different from the installer. This approach introduces liability issues if undiagnosed problems and errors in measurement occurs. The result will be extra work, rework and scrap materials. The survey was the subject of 2 dedicated workshops, the first to reveal areas where there is uncertainty about obtaining accurate condition or dimensional information and the second to design and map the retrofit survey process.

The process map generated is attached to this report (Appendix 1). This illustrates where information can be gathered before or after the on- site survey. With these innovations a below 4 hour on-site survey is much more achievable, but requires robust dataset, collated and cleaned in advance. The next step in designing the survey process is to simplify and optimise the activities needed to capture the data highlighted in the process map. This Includies: how many people? With which skills? For how long? One can imagine a hand-held device being used to collect survey information and then use this to model and cost different solutions. Such tools are likely to greatly decrease the time taken for survey and provide instant feedback to the customer on solutions and costs

4.2 Installation Process

The value propositions developed in work package 4.1 state that an installation time of 1 to 2 weeks is required to achieve mass appeal for whole house retrofit across our target customer segments. Progress in overcoming the following challenges will improve customer acceptance and increase likelihood and speed of take up.

- Provision of Safe, easy and quick access equipment particularly for external wall insulation.
- Systems and products to simplify finishing at the interface between measures, e.g. Windows and external / internal insulation.
- Very thin insulation products to deal with window reveals and other details.
- Standard approaches to deal with existing problems such as rotten floor joists and cold bridges.
- Materials and processes to avoid the use of adhesives, plaster, render and filler which take time to cure.

The installation processes for both external and internal insulation based whole house retrofit were developed during the mapping workshops. These confirm the belief that the value proposition times for installation can be achieved. The internal and external wall process maps / estimates of times are attached (Appendix 2 & Appendix 3). Both of these scenarios illustrate a potential installation time of less than 1 week.

4.3 Through Life

During the mapping workshop on through life support it was considered that it was highly likely that this aspect of retrofit was to be carried out by a separate organisation: Rather than a single entity carrying out the installation and supporting its maintenance. In either case, the need for accurate data and information about the survey, retrofit design and installation become vital to enable an effective service to be delivered.

This service is envisaged as a call centre based activity where requests for service and assistance are routed to appropriate providers and relevant information may also be passed directly to service teams to maximise the possibility of a first visit resolution. For example, if a boiler will not start, the relevant replacement parts may be taken to site by the service engineer, providing boiler make, model and serial number are known. Additional information can be relayed, such as boiler warranties or service contract status, to improve customer service.

The need for data can also be seen as a commercial asset. It is likely that this will have commercial value to other agencies such as, local authorities, HM revenue and customs, and other commercial organisations.

5. Emerging Supply Chain Options

The process design and mapping described above revealed five distinct supply chain configurations. These options emerged through a review of the current delivery options and considering how they might perform delivering the customer value propositions developed in Work Package 4.1. Current delivery is through either large corporate players or a collection of sub-contractors operating in their respective trade silos. To deliver a systems-engineered solution a broader view of the whole house retrofit is needed; the objective is to improve thermal performance at the boundaries between measures and drive up overall quality. In addition it is possible to remove duplication of effort during the survey and installation of the retrofit measures.

The delivery options developed are:

- Leave it to the market
- Large corporate delivery
- Scalable unit model
- Hybrid model
- DIY

The following sections explain the four configurations in more detail and are summarised in in Table 1 Section 5.6.

Each was assessed against the following criteria which define the Value Proposition:

- Functionality - Thermal performance and aesthetics
- Flexibility - The ability to react to customer needs for details of timing, finish, combining other works into the retrofit package
- Dependability - The quality of service delivered by the retrofit company to include quality of installation and finish, punctuality and meeting time and other commitments made to the customer
- Speed- The time taken at any stage of the process: Eg. From initial contact to survey; from survey to installation, or the time taken for the installation itself.
- Cost -The overall cost of the retrofit to include all activities from survey through to installation and through life support.
- Disruption- From the customers' perspective, how much the customers day to day activities are affected by the retrofit. This can be a trade-off between numbers of retrofitters in the home and the overall time taken for the retrofit.
- Trust- The emotional connection made between the customer and the retrofit business and the level of commitment and delivery of assurances given prior to the retrofit installation.

5.1 Leave it to the market

The base-case option is to leave it to the market, with each of the improvement measures effected through the current, vertically integrated and dispersed, supply chains identified in Work Package 4.0. This is the model adopted in Germany & France and we know that this does not deliver the value proposition we have developed from the capability gap analysis in Work Package 4.1. Process duplication drives up costs, increase time on site and lead to poor product quality.

The previous report also demonstrated that, even with incremental improvements to the current model, this measure-by-measure approach was unlikely to enhance thermal performance sufficiently to deliver whole house retrofit on a mass scale. Currently, each trade works within, and is governed by, its own trade related procedures, training , accreditation and values. For retrofit, this means that cross-trade dependencies are not factored in to the process and multi skilled teams discouraged; a paradigm which is reinforced by the (single) trades' related training & qualification structures. Inertia in the existing supply chain will make this the easiest entry to the retrofit market.

This model would also require a project management company to front the operation, which may keep focus on completion deadlines but will add unnecessary costs to the programme and reinforce cross-trade duplication.

5.2 Large corporate delivery

A model for this approach exists – the Decent Homes Programme is an example - where retrofit is delivered by large companies, using a mix of sub-contracted and direct labour teams. Customers have a single interface with the company, who take responsibility for costing, coordination, planning, delivery and risk.

While customers value a single point of contact; experience has demonstrated that overall costs are higher. This is attributed to an aggregation of overheads and profit; an inevitable consequence of sub-contracting the activities. The trade related silos manifest in the above model are evident here too, with the same adverse outcome. Inertia in the supply chain will mean this is a likely model with which to deliver retrofit.

This model is more suited to street by street retrofit rather than house by house due to the administrative overhead required to operate cost-effectively.

5.3 Scalable unit model

A scalable unit model can combine the single point of contact that customers value, with the product consistency, timescale, quality and cost advantages achieved in the large corporate delivery approach. Scalable units can be imagined with the capability to deliver repeatable, standardised retrofit solutions from a single survey, followed by one delivery team.

Supply chains would be integrated as before to facilitate the flow of product design and delivery, specified in the future state supply chain. Target costing, product design, delivery timescales, training requirements, standards and through life servicing would be predetermined, through the national branding/programme vehicle. However, to make the opportunity attractive discrete delivery units may need exclusive rights to install the retrofit measures in a locality. Once a workable model is established it is then scaled up across other locations.

An advantage of this approach is that the delivery units can be locally based enterprises, perhaps with long standing community relationships and a known, trusted brand. From the customer engagement deliverables in Work Package 5 we know that these characteristics are valued by customers and may therefore be critical in securing the customer value proposition in whole house retrofit.

In operation this approach could be realised by an organisation taking the lead in developing working practices and processes and providing a packaged product of training, accreditation, and equipment to provide retrofit services.

There are obstacles to overcome to make this approach practical and viable. Firstly the training and regulation needs, individual competences must be understood to pare down the required qualifications for retrofit; this will industry self and may require primary legislation.

Secondly a robust process for surveying and modelling property will need to be developed to deliver certainty in on site work execution.

Thirdly, to achieve the quality, cost, speed and flexibility requirements for retrofit kit supply standardised lean supply chains will be needed; very different from existing models.

Finally, commercial barriers will need to be overcome and new funding paths created to build retrofit business.

5.4 Hybrid model

Variations and combinations of the above models are possible. For example, a large corporate delivery model could be established to manage the programme on a national basis. It would have primary responsibility for product specification, training and all the main supply chain contracts. Crucially, it would also carry all of the project risk, rather than seek to transfer it through a traditional contracting interface.

On site delivery could then be expedited through contracted alliances or partnerships organised in to geographically focused delivery units. These delivery units would ideally be comprised in similarly large, national undertakings but whose principal expertise is more focused on customer and product delivery. The partnerships would create and foster integrated team values, with the joint objectives of continuous improvement and profit sharing.

Supply chain structures such as these are preferred, for example, on large infrastructure works where high complexity, scale and tight deadlines combine to escalate risk in the project. With risk removed, suppliers and contractors can focus on eliminating problems, rather than managing their effects, and reduce risk, rather than avoiding penalties and/or litigation.

Examples of supply chain structures such as these are evident in the UK water sector, where infrastructure investment of c. £22bn is scheduled over the next five years; UK gas' £30bn mains replacement programme and BAA's £4bn terminal 5 project.

There are a number of downsides to the hybrid model. To be effective contracted partnerships take time to structure, establish shared goals and ethos, and to put in place the necessary contracts and performance criteria. Where this model has been adopted, the process has been likened to that in company mergers, few of which are wholly successful or enduring. These issues may add undue risk to the establishment and rapid deployment of a successful supply chain model for mass retrofit.

5.5 DIY

In this model all interventions are project managed or executed by individual householders. Simple measures such a draught proofing and loft insulation can be achieved by most householders. More disruptive measures, such as wall insulation and the replacement or upgrading of doors and windows, are more likely to require specialist intervention and warranties are desirable to safeguard property values and avoid problems during onward sale.

From the customer value research in work package 5 it is evident that many householders attempt retrofit project management, coordinating trades, often over extended periods, with varying degrees of success. The research, and experience, suggests that this approach leads to costly, sometimes ineffective outcomes and does not easily lend itself to a mass rollout.

5.6 Preferred option

Of the options described above, DIY is unlikely to meet the scale and quality needed to deliver mass retrofit.

The large corporate model carries duplication of effort, high overhead burden and sub optimal supply chain unless the works are being undertaken at the street by street scale. The hybrid model is similar to large corporate but may have the advantage of lower overheads albeit with longer time to set-up.

Table 1: Supply chain assessment

Model / Criteria	Leave it to the Market	Large Corporate	Scalable unit	Hybrid	DIY
Functionality	✓✓	✓✓✔	✓✓✔	✓✓✔	✓
Flexibility	✓	✓✓	✓✓✓	✓✓✓	✓✓
Dependability	✓	✓✓	✓✓✓	✓✓	✓✓
Speed	✓	✓✓	✓✓✔	✓✓	✓✔
Cost	✓	✓	✓✓✓	✓	✓
Disruption	✓	✓✓	✓✓✓	✓✓	✓
Trust	✓	✓✓	✓✓✓	✓✓	✓✓

Qualititative assessment of the relative capabilities of alternative delivery models.

Only at 3 ticks is the model considered fully capable for mass retrofit delivery

✔ *contingent upon enabling innovations for data, tools and work execution (see papa 3.5 & 5.3)*

The scalable unit is the preferred option as this is most likely to deliver the required customer value and a whole house systems engineered product. Retrofit would be delivered by small specialist teams with the appropriate competence and highly effective supply chain. This model will be developed further in Work Package 4.3 where the routes for funding, training and regulation to enable and stimulate will be explored.

5.7 Supporting systems

To support the development of the models described, enabling technologies and innovations identified in paragraph 3.4.2 are needed. This will facilitate step change improvements for on-site processes; these fall into two broad categories and will form part of the input to the change management plan to be developed in work package 4.3.

- **Systematising the survey**
  - Compiling as much property specific data as possible before visiting the site (Externalising) e.g. mapping, planning, utility data.
  - Capture all survey data quickly and accurately including appropriate detail on condition of the fabric of the building,
  - Standardised data recording and processing.
  - Rapidly and accurately completing a customised, costed customer proposal with energy benefits identified.

- **Increase the effectiveness of retrofit works execution**
  - Prefabricating retrofit interventions off-site where possible to secure the design tolerances to reduce installation time.
  - Improving the response time for deliveries to site; ensuring retrofit elements arrive pre-assembled, do not require unpacking or waste disposal.
  - Scheduling deliveries to sequence with installation on site with elements offloaded in pre-defined logical order of use.
  - Adopting a smart [system/production/engineering] approach to work content and sequencing.
  - Providing the appropriate combination of competencies for the retrofit task.
  - Providing robust work methods, tools and products to simplify the installation, minimise onsite improvisation [and eliminate rework].

5.8 Gap Analysis

5.8.1 Survey

Currently each retrofit intervention requires its own survey. This is time consuming, costly and disruptive to clients. A single survey capturing all the information necessary to conduct any intervention and added value option needs to be developed to satisfy the value proposition requirements developed in Work Package 4.1. Significant innovation in surveying technology needs to be created to allow faster and accurate measuring and more detailed assessment of the property type, construction and condition. A robust survey is vital to eliminate risk during the subsequent retrofit installation works and increase the certainty of costing and reducing the safety margin at each process stage.

5.8.2 Skills

The trade skills required to complete a whole house retrofit currently sits across several trades. Our research concludes that the professional retrofitter of the future needs to be multi skilled across several disciplines; in order to satisfy the value proposition of small teams delivering the work and also to maximise the potential time and cost savings. The current position of independent trade training, qualifications and accreditation reinforces the existing silo behaviour and the inherent duplication this involves.

5.8.3 Training / Accreditation

A gap exists in creating training courses and accreditation bodies prepared to develop the necessary skills for whole house retrofit as discussed above. Training must be geared to competences required to deliver not only the retrofit measures but compliance with legislation / accreditation requirements and deliver the quality that customers demand. In addition full quality assurance and back up must be delivered to provide the value customers demand.

5.8.4 Legislation / Regulation

There are areas in the current building regulations and compulsory legalisation that will need to be challenged to enhance the future retrofit process and cost. Example areas include the removal of building inspector checks and the adoption of wider self-certification; consistent and uniform policy on health and safety, waste management and licensing. A competence based approach to retrofit is needed cutting across the current trades skills and qualifications, this will allow more effective working on site and a simpler route to trade qualifications which will be needed as the retrofit programme rolls out. Much of this topic will be cover in WP6 in collaboration with this work package.

5.8.5 Programming

A further skills gap has been identified between the survey and installation stages of a retrofit. A programme planning role will be required to understand the survey data and develop a technical solution and an installation programme which meets not only the intervention requirements but also those specific to the client. Examples may include working during weekdays or weekends only, or conducting the works to coincide with holidays. This role needs to remove the requirement for installers to problem solve on site, and allow them to focus purely on installation.

5.8.6 Products / Process

Construction products themselves help determine the time taken to complete works. Wet products in particular are identified as a key area of potential innovation. Current drying times are significant and unavoidable and product innovation needs to focus on either removing the requirement for or reducing the current process time. Examples of such conditions include foundations with poured concrete, floor screeds, renders and plasters.

From the cost analysis, labour time should to be the key area of change for significant cost reductions to occur. This ambition has to reflect a balance of both improved skills (professional retrofitter teams) and processes driven by products plant and tools which will facilitate a faster installation. Potential product innovations that have been identified are listed below and enabling technologies in paragraph 3.5

- Laser survey measuring of dimensioning to facilitate off site production.
- Material identification tools e.g. type of glass in windows.
- The ability to measure wall thickness, make up, location of services, condition of ties and any existing insulation.

- A projected grid system for EWI / IWI which is displayed onto the wall being worked on which allows installers to see exactly where and in what order the insulation needs be installed.
- Electrical extenders for IWI to allow sockets and switches to be easily adjusted.
- Prefinished insulation which only requires work around joint details.
- Non-mechanically fixed insulation.
- EWI loading and fixing machine operated from ground level

6. Costs

6.1 Current Costs

A range of retrofit solutions have been costed using current materials and installation processes. The results are shown in Tables 2 to 4 below.

This illustrates the cost of a measure by measure approach and the benefits of combining selected solutions / product packages. The packages were chosen using a "sensible" approach before different scenarios could be tested using the energy model developed in Work Package 1. These sensible packages were labelled bronze, silver and gold; bronze package comprised the core necessary interventions, with customer value options progressively added through to gold.

The base line house chosen is 1930's 2 storey semi-detached house with solid walls, single glazed windows and minimal loft insulation.

Table 2: Measure by Measure Retrofit Costs

Item	Labour	Materials	Prelims	Overhead	Profit	Total
100mm External Wall Insulation	£2,287.60	£5,863.40	£626.51	£486.77	£265.51	**£9,602.64**
Internal Wall Insulation	£1,922.63	£7,991.98	£610.13	£592.09	£322.96	**£11,680.33**
Door Front	£104.80	£418.00	£149.82*	£31.22	£17.03	**£615.91**
Door Rear	£102.20	£392.00		£29.51	£16.10	**£582.21**
Windows	£1,083.92	£3,774.17	£330.11	£290.12	£158.25	**£5,723.28**
Loft Insulation	£150.75	£74.25	£141.00	£13.44	£7.33	**£265.07**
Boiler	£383.89	£1,075.31	£291.73	£87.14	£47.53	**£1,719.08**
Floor Insulation	1885.95	725.85	£393.87	£155.97	£85.08	**£3,076.94**

*both doors replaced together

Table 3: Packaged Measures EWI

External Wall Insulation Solution	Labour	Materials	Prelims	Overhead	Profit	Total
Bronze (EWI plus Loft insulation)	£2,438.35	£5,937.65	633.66	460.68	284.11	**£9,754.45**
Silver (Bronze plus Doors &Boiler)	£3,029.24	£7,822.96	659.05	633.12	364.33	**£12,508.70**
Gold (silver plus floors & windows)	£5,999.11	£12,322.98	740.58	1048.45	603.33	**£20,714.45**

Note that Cavity Wall insulation has not been included in the measures here. It is unlikely that this measure alone will result in the required insulation U value, resulting in either Internal or External wall insulation being required in addition.

Table 4: Packaged Measures IWI

Internal Wall Insulation Solution	Labour	Materials	Prelims	Overhead	Profit	Total
Bronze (IWI plus Loft insulation)	£2,073.38	£8,066.23	612.58	591.37	340.31	**£11,683.86**
Silver (Bronze plus Doors & Boiler)	£2,664.27	£9,951.54	636.98	728.9	419.45	**£14,401.14**
Gold (silver plus floors & windows)	£5,634.14	£14,451.56	1067.38	1163.42	669.5	**£22,986.00**

The choice of internal or external measures will be based on the balance between speed of installation and perceived benefit in terms of aesthetics, comfort and disruption. It is clear the internal wall insulation will be more disruptive and likely to be more expensive. There is also a greater possibility of overheating in hot weather with the change in thermal mass. External wall insulation has the advantage of confining works to the outside of the property with the balancing negative of difficulty of access /working at height and some details such as perforations for waste pipes and fixing satellite dishes and rainwater goods.

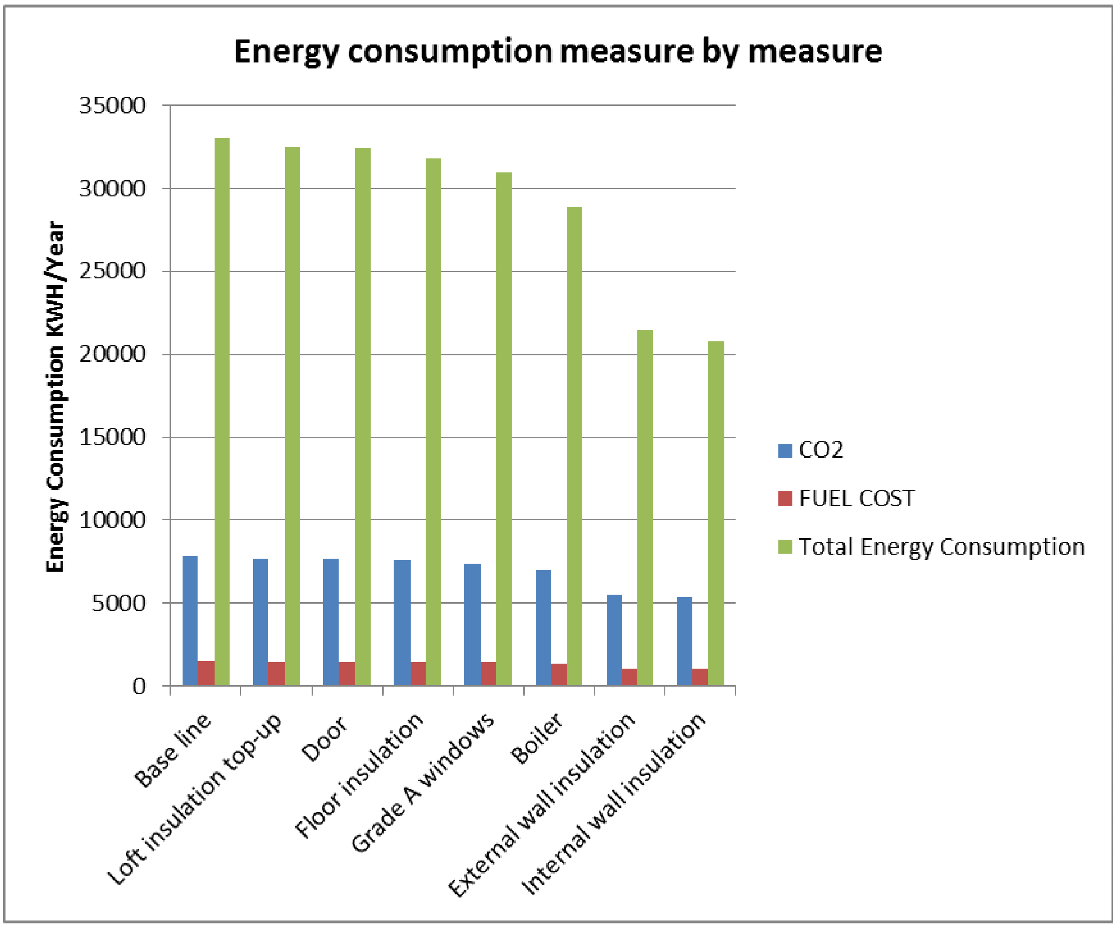
6.2 Cost / Benefit

6.2.1 Benefit of individual measures

Each of the above measures was modelled against the base line thermal performance of the chosen house type. Data has been generated from the Work Package 1 *Single Dwelling Model* in its Beta-test version. Consequently the results must be used with some caution; energy consumption for all scenarios include appliance loads which somewhat understates the benefits of the measures analysed.

The results are shown below measure by measure and package by package

Figure 2 Evaluation of effectiveness of each retrofit measure

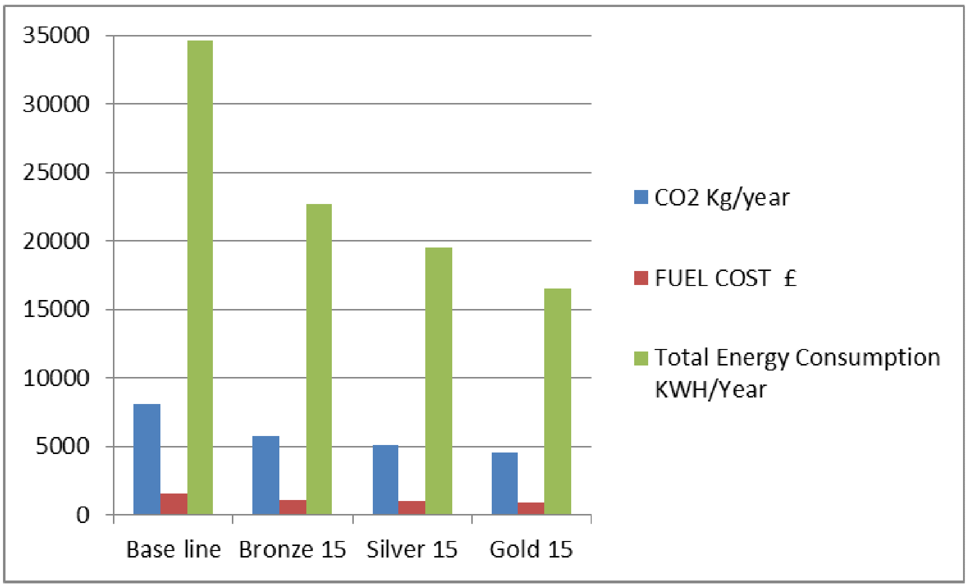


The above table illustrates that the most effective measures are internal / external wall insulation followed by an A rated boiler.

6.2.2 Benefit of Packaged Measures

The bronze, silver and gold packages were modelled against the thermal performance of the base line house. The results are shown in the table below.

Figure 3 Energy bills plotted against packaged retrofit measures



From Figure 3 it can be seen that energy bills for the base line house are £1459 per year, whereas with the bronze package they are £1142, with silver £1018 and gold £897. These figures were calculated with an air permeability rate of 15. Sensitivity to air permeability is included in the following results.

6.2.3 Packaged Measures

The chart in Figure 4 below illustrates the effect of air changes per hour (Air Permeability) and upgrade package against annual fuel bills for the chosen house type

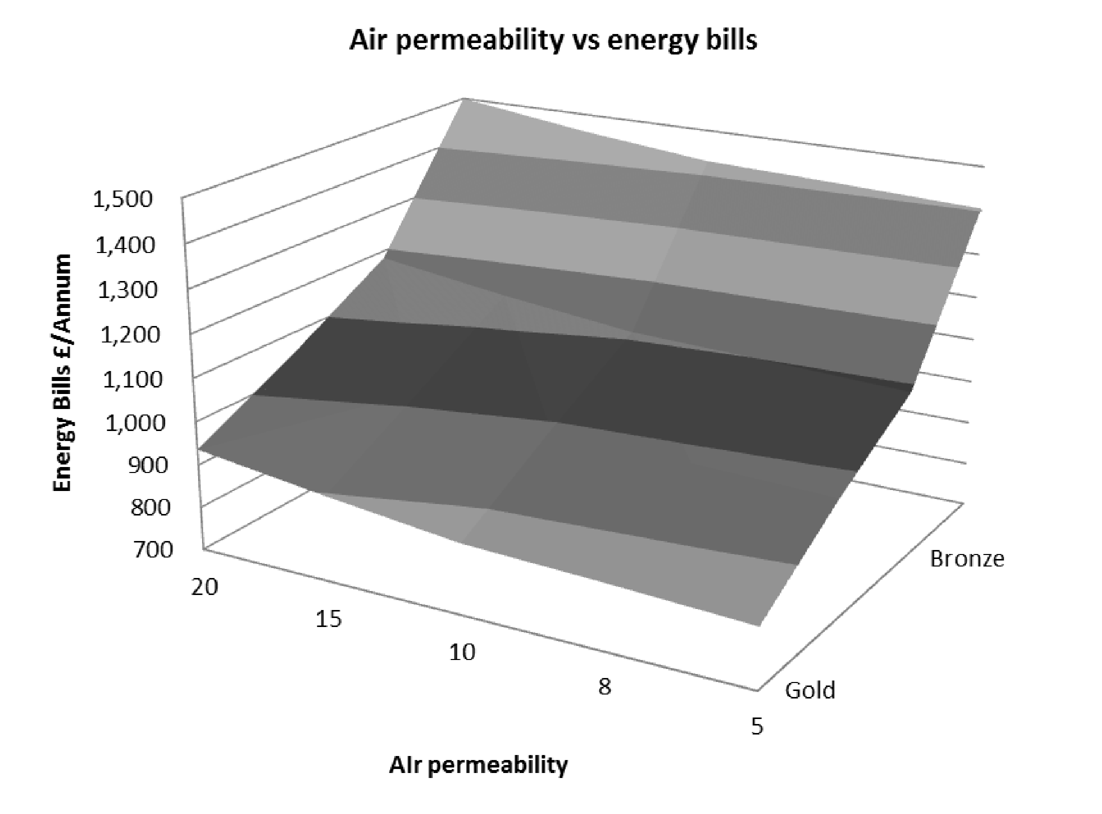


Figure 4 Energy bills plotted against retrofit package and air permeability

This illustrates that air permeability does not have a highly significant impact on the overall cost to heat the house, this was not as anticipated.

6.2.4 Cost benefit.

The overall cost / benefit is shown below as the reduction in annual fuel bill against the cost of retrofit. Two illustrations are given below, the first for the cost of retrofit now, and the second for cost to retrofit in future taking the cost evolution over time data from paragraph 6.3 of this report.

Table 5: Cost benefit - Current Costs

Package	Energy Use KWH	Energy saving KWH	CO2 emissions KG/Year	CO2 savings KG/year	Energy bill	Energy saving	Cost of measure	Payback Years
Base	34,614	0	8,131	0	£1,543	0	0	0
Bronze	22,642	11,972	5,761	2,370	£ 1,135	£ 408	£ 9,754	23.9

Silver	19,466	15,148	5,132	7,619	£ 1,026	£ 517	£ 12,508	24.1
Gold	16,558	18,056	4,556	3,575	£ 927	£ 616	£ 20,714	33.6

Table 6: Cost benefit - Eroded Costs

Package	Energy Bill	Energy Saving	Cost of measure	Payback Years
Base	£1,543	0	0	
Bronze	£1,135	£408	£5,947	14.75
Silver	£1,026	£517	£7,627	14.75
Gold	£927	£616	£12,630	20.5

From the above tables it can be seen that the payback time based on current energy and installation costs is very high across the board. Notably the boiler, and potentially windows / doors, will need replacement within the payback period. For the cost eroded example payback times are reduced, but remain higher than would be attractive to consumers. Energy saving and payback are not considered to be the sole motivation to encourage people to retrofit: Home aesthetics, comfort and 'peer perception' will play an important part. Even if the payback were below 10 years there need to be other compelling aspects of the Value Proposition to get the market to shift.

6.3 Cost evolution over time

In a truly competitive market costs will decrease as providers seek a competitive edge: Cost being one tool to win business. There are a range of approaches to reduce costs as listed below, but it should be noted that there is interaction between these. ie. Offsite fabrication will reduce labour time and cost but increase materials cost.

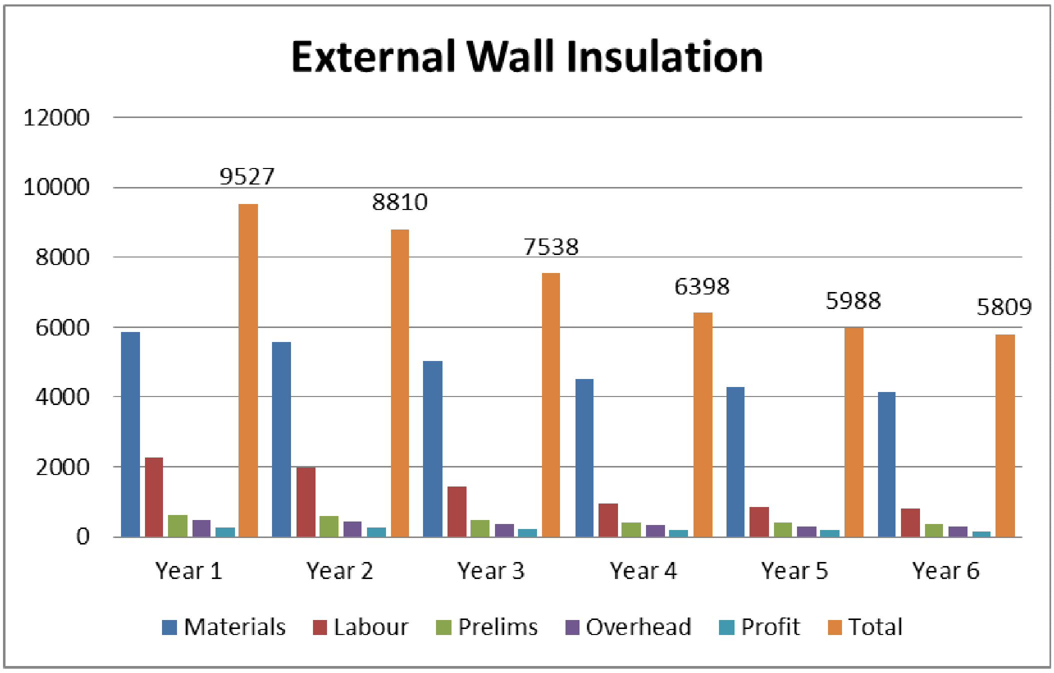
This illustration is constructed using experience gained in other industries where there are similar labour and material ratios. This cost decay illustration has been completed for external wall insulation. Similar cost decay can be expected for other solutions, although the ratio of labour to materials may have a significant effect.

- Offsite fabrication (considered to be worth 30% of labour saving with an increase in material cost offsetting 50% of the labour saving.
- Decreased labour through standard work and improved methods (worth approximately 30% over 5 years.
- Value engineering of existing products (Worth approximately 10% over 5 years).
- Product cost decay (premium products becoming the norm) Worth approximately 10% over 5 years.
- Increased volume and competition.
- Improved access equipment design and availability.
- Better and more cost effective materials / solutions.

- Problem solving products becoming available.
- Centralise data systems meaning elements of survey work can be completed prior to site visit, and through life support is more effective.
- Improved logistics – site specific kits with zero packaging to improve labour utilisation on site (worth approximately 10% of labour over 5 years).

It is expected that over time disruptive propositions will appear that change the shape of the market. An example of this is A rated domestic appliances: Since it has become mandatory to display the energy rating energy performance has become much more important to consumers and poorer performing products have disappeared from the market.

Figure 2.Illustration of how costs could erode over time is shown below.



In summary it is predicted that over a period of 6 years the cost of installing external wall insulation will fall from the current £9,500 to £5,800.

The rate of cost decay could be further accelerated by a disruptive body entering the market, if this body was comprised of small scale able units this could provide stimulation to the market accelerating take up of whole house retrofit and inject inertia into the industry.

The reference cases used above are different from those used in Work Package 3.4a, for meaningful contrast of design and supply chain impacts common references will be used going forward.

The other industries mentioned above in reference to decreasing cost over time are capital goods manufacture and automotive; these are considered to be fairly mature in their adoption of lean manufacturing techniques and the labour savings and product cost decay specified below are considered achievable if not modest.

Example 1. Manufacture of a complex opto-electronic printing product.

- Product assembly time reduced from 39.8 hours to 25.4 hours; a 36% reduction
- Rework eliminated 2.8 hours per machine.
- Off site assembly used to eliminate non-core asembly work, resulting in a labour saving of £263 per machine against increased material cost of £189 per machine
- Material cost reduction of 20% achieved over a 6 month period through improved machine utilisation (Changeover Reduction activity) parts rationalisation and design for manufacture changes

Example 2

Door manufacture

- 20% labour reduction achieved through improved job design and standardisation
- Throughput time reduced from 4 days to 4 hours
- Permanent removal of work in progress of 200 units at £350 each
- Above achieved through the introduction of flow and “pull” production system.

The above case study summary results were achieved using lean tools and were completed over, 60 days for the opto-electronic example and 120 days for door manufacturing. No major capital expenditure was required in either example.

7. Qualitative Review of Finance

This research and review has focused on the technical delivery aspects of the Retrofit Supply Chain. For the retrofit market to take-off and thrive there also needs to be consideration of the finance issues which both:

- Fund investment in the supply chain.
- Ensure that the insurance market takes a positive view of retrofit.

7.1 Investors / Funders

The construction industry is known as a conservative and risk-averse sector with much lower investment and innovation than, for example, consumer goods and aerospace. The industry is comfortable with the truism ‘We are in a rush to be second to market’. This is borne of experience from product and design innovations which have not proven successful first time.

The sector is not seen as attractive to investors with low returns (single digit, or even 1% margins) and susceptibility to market downturns.

This may leave a way open for new players in the market with a more service and consumer led offering and see the potential of retrofit as a ‘style’ as well as energy saving offering.

The UK Government remains upbeat about the potential ‘Green Economy’: With 25 million homes in the UK needing retrofit there is a need for new offerings. However the stimulus for this market falls somewhere between the Departments of Energy & Climate Change (DECC), Communities & Local Government (DCLG) and Business Innovation & Skills DBIS.

A significant output from this project will be to give clarity of where best to stimulate the market without over subsidising the first movers.

7.2 Insurance

Insurance was identified as an area of potential risk for to retrofit in four ways:

- If Retrofit causes or exacerbates deterioration of the retrofitted property.
- If suppliers (product an installation) make errors which undermine the credibility of the sector.
- If products underperform in their energy saving, aesthetics or design life.
- If retrofitted properties are more expensive to rectify after common home insurance claims.

With a robustly designed retrofit offering these negatives can be turned into positives:

- Reducing the general deterioration of a property and hence risk if loss to insurers and mortgage lenders.
- Collectively accredited and self-insured to a level where there is a trusted retrofit brand or quality standard.
- Able to offer guaranteed levels of performance and life (within measurable parameters).
- Create robust solutions which are more tolerant of mishaps (eg: Flooding and damage) and / or quickly and cost effectively replaceable

7.3 Summary

To date there has been little appetite from the finance community to engage with the project and explore the potential for retrofit to offer new opportunities. Moreover, the team have not found a mechanism to engage financial expertise in generating a 'requirements specification' which meets the needs of investors and insurers.

Now that draft, but tangible, retrofit supply chain hypotheses have been developed there will be opportunities to have more specific discussions with individual organisations.

8. Next steps and conclusions

8.1 Next Steps

8.1.1 Supply Chain configuration

The configuration of the supply chain is of great importance and our challenge is to facilitate the breaking down of functional barriers within and across the supply and service elements of the supply chain.

Of particular interest are:

- The point of consolidation of product prior to delivery to site
    - Consolidation and geographic location of stock holding to maximise speed through the supply chain
    - Configuration of stockholding units, national, regional and local

- How different players in the supply collaborate to exercise power and influence
- Configuration of the supply chain to remove duplication and strip away areas where multiple layers of margin exist

8.1.2 Competence and training

Throughout the workshops held during this work package a common stumbling block has been identified as the silo nature of the supply chain and how an integrated supply chain would improve flexibility and efficiency. Current regulations dictate the level of qualification individual trades must hold in order to carry out certain tasks and certify their work. For example to change a boiler a full gas safe accreditation is required but only part of the broad qualification is needed to carry out the work safely and effectively. Changing the accreditation required would simplify the route to scaling up retrofit activity and allow small companies to enter the market more readily and cost effectively.

8.1.3 Data

The need for access to accurate site data has been highlighted at each workshop, and for each stage of retrofit. Where this data can be sensitively shared there is a major opportunity to reduce the cost of duplicated collection.

- Survey
    - To gather as much data as possible about a property prior to the site visit to reduce time spent on site.
- Installation
    - To record what is installed, quality control information, problem log for feedback to design and supply teams to allow continuous improvement
- Through Life
    - To retrieve information about the installation, what was done, when and by whom, if it is in warranty / under service contract and hence who pays for remedial work or service. Problem information can be used to improve product and installation performance.

8.1.4 Demand management

To monitor demand to optimise national stock holding systems catering for regional differences in product and demand

8.1.5 Scaling Capacity

A plan is needed to:

- understand the competences required for retrofit
- Train suppliers appropriately

- Provide materials and retrofit systems that are fir for purpose and simple to install
- Provide the investment to upscale manufacture of materials and labour provision for retrofit

8.2 Conclusions.

Through the work completed for this stage of retrofit supply chain development major themes have emerged which will be explored in the next phase of work (work package 4.3)

- The current supply chain is split by silos around the existing trades:
    - Windows and doors
    - Loft / Roof insulation
    - Heating and plumbing
    - External insulation
    - Internal insulation
- Delivery of retrofit is centred on these trade silos resulting in duplication in the supply chain and retrofit installation businesses
- There is a piecemeal approach to retrofit design and installation again split by function resulting in a failure to achieve the performance and cost benefits of a systems engineered approach
- The skills and qualifications demanded to work legally and to satisfy warranty provisions with products used in retrofit are mostly general and not “right sized, and fit for the purpose” for a future mass retrofit market
- The existing supply chain is not configured for the retrofit market (which has yet to emerge) and there is no clear strategy for distribution and consolidation of products to effectively support and enable retrofit businesses.
- Routes to obtain funding and investment in domestic retrofit are unclear and the team has been unsuccessful in engaging with the financial community on this project. The green deal may include mechanisms but is unlikely to enable the whole house retrofit systems approach.
- The survey process requires in depth study to provide a robust system to remove risk from the retrofit process. This is likely to include a large element of continuous monitoring, feedback and improvement as the industry forms and matures.
- Current trade skills are inappropriate for retrofit being broad based with limited cover for cross trade working. The retrofit installation process also requires in depth study to understand the basic competences and optimise team working to achieve the best value balance of number of people on site and time taken for retrofit.

- Trade qualifications and legislation for working with gas, water and electricity are likely to limit the speed and effectiveness of the development of retrofit unless reviewed and brought into line with the competence approach suggested here.
- New products are required to simplify retrofit activities and increase the robustness of the end result. Pre fabrication and off site material preparation are also seen as a requirement to increase speed and quality of installation results.

The work for package 4.3 will concentrate on the main elements stated above. The biggest challenges are seen to be developing a robust survey process and understanding the competences required for retrofit. Also key to delivering affordable and effective retrofit is configuring / developing the supply chain to deliver the right products, in the right form and quality, at the right time.

Appendix 1-Survey Process Map

TotalFlow_Survey_In
stall_Process_FINAL_

Appendix 2-Extenal Wall Process Map

EWIprocess
map.pptx

Appendix 3-Internal Wall Timings

IWIinstallation
process.docx

Appendix 4 – FMEA workshop summary results.

Surveyfmeaanalysis.
xlsx

installfmeaanalysis.xl
sx

Appendix 5 – Workshop presentations and attendance

ETI Workshop
attendees.xlsx

7thSept1.ppt

8thSept1.ppt

9thjune.ppt

12th july.ppt

13thSept1.ppt

istSept1.ppt