Programme Area: Smart Systems and Heat

Project: WP1 Building Retrofits

Title: Project Conclusions and Opportunities for Improving the Delivery of Whole House Retrofit

Abstract:

This report is Part 2 of the two-part summative report for the Energy Technology Institute's Domestic Retrofit Demonstration project, part of the Smart Systems and Heat (SSH) programme. The underpinning hypothesis for this project was that the Retrofit Approach can be developed to meet the targets set in the ETI's Optimising Thermal Efficiency of Existing Housing project and viably deliver domestic retrofit to large numbers of dwellings. This report draws conclusions and makes recommendations for the future.

Context:

The aim of the project is to validate the cost, time and energy effectiveness of domestic retrofit across different house types, using an approach that could be employed to improve the energy efficiency of the vast majority of the existing 26 million homes in the UK which will still be in existence by 2050. The novel, mass-scale retrofit approach being tested was first developed in a deskbased ETI project ("Optimising Thermal Efficiency of Existing Housing") completed in 2012, as part of the ETI Buildings programme. The 20-month long, £475,000 project will retrofit five types of domestic property, identified and prioritised in the earlier ETI project.

Smart Systems and Heat (SSH) Technology Programme

Domestic Retrofit Demonstration

Project Summative Report 2

Project Conclusions and Opportunities for Improving the Delivery of Whole House Retrofit

Content

1. Executive Summary

This report is Part 2 of the two-part summative report for the Energy Technology Institute's Domestic Retrofit Demonstration project, part of the Smart Systems and Heat (SSH) programme. The underpinning hypothesis for this project was that the Retrofit Approach can be developed to meet the targets set in the ETI's Optimising Thermal Efficiency of Existing Housing project and viably deliver domestic retrofit to large numbers of dwellings.

A number of key processes and aspects of the Retrofit Approach have been tested in the demonstration houses, including survey, design and installation processes, energy performance, as well as supply chain and consumer acceptance.

Through the insights gained in the project, this report seeks to evaluate the effectiveness of the end-to-end delivery mechanism of the Retrofit Approach (Chapter 4), to identify the market opportunities (Chapter 5) and to align these opportunities to potential commercial models (Chapter 6), in order that the Retrofit Approach can become commercially viable for delivery at a larger scale (Chapter 7).

Some of the key findings from our evaluation are as follows:

Efficient and advanced survey methods are essential to identify the underlying conditions of the property. Our research highlighted the need for additional tests to give a more reliable understanding of underlying building condition without incurring excessive cost. An example is an addition to the pull out test used by the EWI system suppliers to include a push-in test to ensure that the wall will not collapse inwards; or alternatively new test apparatus to assess wall integrity, possibly using ultrasound.

A library of standard installation details and technical solutions has been proven to reduce time and hence cost at the design stage. It can further reduce time and cost on site if the team leader or a roving design coordinator have been trained to make necessary design decisions on site rather than seeking advice from the designers in the office. The development of a cloud based details library and linked decision tool would support this. The details in the library should respond to the various building constructions and vernacular details which are applicable to house types of different eras and within different regions in the UK, such that there are standard details for the majority of the retrofit situations that an installer may encounter. The retrofit details should be developed by an experienced architectural or surveying consultancy which has extensive experience of whole house retrofit in conjunction with the insulation manufacturers and insulation system providers. This combined expertise will ensure the details are technically robust and meet the typical warranty requirements of manufacturers.

High performance insulation and building products used in the Retrofit Approach are still at the top end niche of the market. Further innovation and development of products and manufacturing processes are needed for better technical performance and reduced cost, as well as reducing installation times and weather dependency. Consideration and development of "off-site" processes such as pre-finished insulated wall panels will provide more certainty of programme and costs, by minimising the risk of weather delay through avoiding the current practice of wet applied render finish which is adversely affected by cold temperatures and rain. The majority of external render finishes will not cure in cold temperatures (typically below 5^{o}C) and precipitation will damage the render as it cures, thus in such weather periods, work on EWI render systems cannot be undertaken, causing delay to the work programme.

Installer productivity is a major opportunity for reduced programme periods and resource costs, however productivity must not be prioritised over quality otherwise the Retrofit Approach cost and technical performance targets will not be achieved. The construction sector typically does not have a strong history of process and product innovation to improve productivity. Therefore, it may require regulatory requirements, or a new entrant to shift the market. An ambition to innovate aligns well with other current (2016) activity in construction: continued emphasis on the Construction 2025 Commitments[1], the Construction Leadership Council focus on Smart Construction and Industrialisation, and a review of the industry-funded CITB (Construction Industry Training Board). This suggests that there will be an appetite

[1] 50% less project time, 33% lower cost, 50% less energy consumption, 50% improvement in trade balance (value added in the UK)

to invest in genuinely transformed capability; and retrofit has the potential for 40%+ increase in productivity, a huge national need for improved homes and a number of innovators determined to enable the transformation.

It is evident from the demonstration houses that when the retrofit measures are installed correctly there is a significant improvement to the thermal performance of the property, which in turn proves the Retrofit Approach target saving for heat energy consumption. More frequent and more robust quality inspections by the team leader or a roving manager are key to ensuring the Retrofit Approach performance targets are achieved on future projects. This demonstration project was an exception to standard retrofit delivery in that the design team was often on site and the quality checks where undertaken as part of the overall observation tasks on the project. Typically quality inspections would not occur so often, possible only at the end of the installation works and often not to the required checking accuracy, sometimes inspections are not undertaken at all and substandard installation work is not rectified.

The supply chain is not yet set up for delivery logistics to individual home retrofit projects. Regular small deliveries to site will minimise disruption and support productivity improvement, but greater market scale is needed to attract suppliers to develop their logistics models. When system providers provide a 'One Stop Shop' for full retrofit kits this will enable greater time and cost efficiencies for the Retrofit Approach and reduce material wastage.

Our research from the demonstration houses has led to a deeper and richer understanding of the practicality and viability of the Retrofit Approach, and has allowed us to identify a roadmap to develop industrial capability for the Retrofit Approach (Chapter 8).

2. Introduction

This report summarises the findings of the Energy Technology Institute's Domestic Retrofit Demonstration project, presents conclusions and sets out future opportunities for the Retrofit Approach. Readers should refer to Report 1 - Key Performance Results of the ETI Retrofit Demonstration Project for the background to the project including retrofit approach definition, a description of the retrofit measures installed at each home and the installation and post-retrofit performance evaluation findings.

2.1. Project Hypotheses and Targets

The underpinning hypothesis for the project was that the Retrofit Approach can be developed to meet the targets set in the ETI's Optimising Thermal Efficiency of Existing Housing project and viably delivered at scale.

The core aspects of the Retrofit Approach are:

- Whole house retrofit – rather than individual measures
- A poly-competent team of 4 people to deliver the whole works
- A significant saving in heat energy
- An installation programme of 2 weeks or less
- A total cost which is likely to be attractive to property owners

The Retrofit Approach included two tiers of target performance as set out below:

Retrofit Approach RetroFix™ Performance targets:

- Targeted primary energy consumption reduction: 25-40%
- Installation Process (time): Maximum 2 weeks
- Capital Cost: £10,000

Three homes had RetroFix™ measures installed; references RD1, RD5 and RD9, all of which are social rent tenure.

Retrofit Approach RetroPlus™ Performance targets:

- Targeted primary energy consumption reduction: 40-60%
- Installation Process (time): Maximum 3 weeks
- Capital Cost: £15,000-£20,000

One home had RetroPlus™ measures installed; reference RD27 which is privately owned.

2.1.1. Energy Performance

The demonstration trial retrofit packages were designed to meet the energy reduction targets set out above. Based on the previous modelling work carried out by the project team for the ETI Optimising Thermal Efficiency of Existing Housing project, the potential for savings in delivered energy consumption ranged as follows:

- 25%-40% saving for RetroFix™, reducing a typical £1,200/year energy bill to £720-£900 (equivalent to annual energy consumption between 7,580kWh and 31,300kWh after retrofit)
- 40%-60% saving for RetroPlus™, reducing a typical £1,200/year energy bill to £480-£720 (equivalent to annual energy consumption between 6,530kWh and 20,700kWh after retrofit).

These figures are for delivered primary energy only (referring to gas boilers and the associated losses due to the efficiency of the boiler) and including ventilation fans, lighting and appliance use, as well as water heating use, effectively all energy use in the home except electrical appliances. It should be noted that boiler and heating control replacement, lighting or appliance upgrades did not form part of this retrofit project at ETI's request, although boiler and heating controls are included as part of the standard Retrofit Approach packages.

2.1.2. Installation Process and Programme

The objective for the installation processes is to minimise disruption to householder's in-situ by developing a short retrofit programme which has limited impact on the residents' use and enjoyment of their home.

The target installation time for a terraced or semi-detached property is two weeks or less for the RetroFix™ scenario and three for the RetroPlus™, while a typical programme for undertaking a business-as-usual External Wall Insulation (EWI) for a semi-detached property would be three to four weeks. The reduction in programme (installation time) is a direct result of productivity improvement, which also enables a significant reduction in costs both of labour and overhead.

2.1.3. Retrofit Costs

The ETI's Optimising Thermal Efficiency of Existing Housing project identified that few owner-occupiers are willing or able to invest more than £10,000 in a home-improvement project.

In addition a simplified Net Present Value calculation from the project suggested that the Net Present Value of Retrofit to the householder is less than £8,000 for a typical 3 bedroom property. This is based on an average £1200/year energy bill, 40% heat saving from retrofit, with a 40 year lifespan of the solutions.

This led that project team to set a benchmark cost of £10,000 for the RetroFixTM scenario and between £15,000 and £20,000 for the RetroPlus™. This led to a benchmark for the Retrofit Approach cost to be set at £10,000 for the RetroFix™ package and between £15,000 and £20,000 for the RetroPlus™.

3. Key findings from the project

The key findings from the project are set out in Report 1 and are summarised below:

Survey and Design

- **Survey** – detailed surveys are imperative to informing the design solutions and installation methods, also supporting the achievement of the required post retrofit performance targets. The current costs of the required surveys are prohibitive to achieving the Retrofit Approach target retrofit cost.
- **Design solutions** - a suite of standard details should be prepared for use across similar housing typologies to reduce the upfront design costs on each project and the time taken to make decisions on site. Standard solutions also enable installation teams to become more familiar with the details, thus reducing the installation programme and enabling installation quality to be improved.
- **Thermal performance targets** as set out in the Retrofit Approach are achievable through the use of appropriate high performance insulation products, good technical detailing and adherence to quality on site. The air permeability targets are more difficult to achieve in occupied homes and in particular in more modern homes with plasterboard internal linings rather than traditional plaster wall finishes due to the void behind the plasterboard.

Cost and Value

- **Costs and Installation Processes** have been reviewed in detail and significant opportunities have been identified to improve product, process and costs. However, a proven route to achieving the £10,000 cost target for a typical 3 bedroom semi-detached property has not yet been established.
- **Material costs:** Significant material discounts are possible on volume purchases, but wastage is endemic (including system generated off-cuts). Brick slip finishes have an appealing aesthetic (vs. render) but come with a cost and labour time premium. There is a need for innovation in heating and ventilation solutions which enable rapid installation – particularly at system interfaces.
- **Labour costs:** Currently EWI installers are paid close to minimum wage, but in its analysis the project team has used living wage and typical trade rates. This puts a cost premium on the poly-competent team approach, but provides a realistic means of achieving repeatable quality results due to employee satisfaction.
- **Overheads** are significant costs for scaffolding, welfare facilities, management and including profit. Further process improvement and procurement will reduce the impact of overhead costs. Setting fixed fees for profit will incentivise a focus on short programmes and right first time quality.
- **Spin-off benefits** are those additional maintenance and improvement items which come 'free' as part of the Retrofit Approach (e.g. gutter clearance) and they are valued by residents. However, despite a potential £1,000 benefit from the works, few recognise investment in property maintenance as a reason to trigger retrofit.
- **Added-Value & Cost Co-Benefits:** Retrofit works have the potential to enable added value works (e.g. roof fascia & soffit replacement) at a marginal cost, through use of the scaffold and the already on-site team. However, whilst the RetroFix™ price-point exceeds £10,000, this may limit the market.
- **Installation Programme:** The cost analysis demonstrates that it is crucial to achieve an installation programme of two working weeks or less: More than two weeks for a four person team will exceed the target cost. Two weeks also supports the householder tolerance for work on their home. This target was only achieved on one house in the project, but with improved material supply, technical solutions and installer training, it will be attainable.

Delivery and Performance

- **Supply Chain** - the supply chain is not yet ready for individual home retrofit delivery logistics at a small scale (a few homes in disparate locations), greater scale is required to enable the supply chain to see commercial benefit in adapting delivery models to provide the frequent delivery service required, enable greater time and cost efficiencies and to reduce material wastage.

- **Installation Quality & Detailing:** Retrofit installation teams generally have standards of quality and attention to detail below the Retrofit Approach requirements for retrofit performance and consumer acceptance. Requirements of the Retrofit Approach need to be clearly set out and reinforced, and products / processes adapted to ensure that teams can be capable of repeatedly meeting the aesthetic and thermal standards.
- **In use heat testing** works with residents' in-situ but would benefit from further validation as four homes are not deemed to be a wide enough trial to sufficiently validate a test method prior to industry commercialisation of the test. Data collected during periods with cold external temperatures are crucial to the test's success as a greater than 10°C difference is required between internal and external temperatures. Heat gains from the sun through windows should also be avoided as it confuses the test results.
- **Energy Performance:** Data analysis confirms the potential for 20% to 50% gas consumption reduction through retrofit**.**

Risk Management

- **Risk:** The risk of cost escalation and programme delays due to issues related to the building condition, particularly on older properties, has been confirmed as having an impact on the contractors proposed capital costs. Inclement weather causes delay to external retrofit installation work and can cause damage to external render finishes. More intensive survey methods, new commercial risk models and the development of new products/construction processes which are not weather dependant are needed to manage these risks and reduce the time and cost impacts of them.
- **Condensation and mould growth** are major risks for the health of householders and also increase the risk of deterioration of building fabric. Work during this project and elsewhere by PRP and others, has demonstrated the need for minimised thermal bridging on retrofit projects as well as adequate ventilation. If insulation is missing in places or not continuous at corners of the house, following a whole house retrofit, or windows are not upgraded to a good thermal performance standard when within a newly insulated wall, or good levels of ventilation are not provided in the house, then condensation and mould may occur in a retrofitted house on the colder surfaces. The use of standard installation details and adherence to on-site quality through a system of regular inspections and undertaken by the team on the retrofit demonstration project, will when coupled with adequate ventilation in the home do much to help to avoid condensation and mould occurring.

4. Effectiveness of the end to end delivery mechanism of the Retrofit Approach

This section gives an overview of the survey, design, installation and supply chain processes for retrofit including insights gained, the requirements going forward, and the challenges experienced throughout the process. The recommended improvements are presented in Sections 4.4. The Retrofit Approach – gaps and issues and 4.5. Barriers.

4.1. Survey and Design Process

4.1.1. Survey Process

The survey of an existing house is time consuming and there are often underlying conditions that often cannot be identified as they are not visible. The time expended on the surveys is costly but the information that is gathered is essential in order to minimise retrofit installation costs, minimise risk and maximise the installation quality and resulting performance. Typical surveys are listed below:

- **Measured survey**

A measured survey is critical so that technical solutions can be specified and the material quantities can be accurately calculated (for later ordering) and costed.

- **Visual condition survey**

The visual condition survey is important as it identifies many of the existing defects, installation barriers and risk items such as potential asbestos.

- **Thermal image and air permeability**

These surveys are not typically undertaken on conventional retrofit projects but they are very helpful in identifying where existing parts of the home are not insulated and what the home's air permeability is, enabling technical mitigation solutions to be developed. Thermal image surveys can only be undertaken in colder months which are restrictive and can impact on the project start times. Surveys carried out during the winter months, with a delayed start for the installation work of a few months may not be an attractive proposition for potential customers. However, render cannot be installed in very cold conditions so winter-time installation is far from ideal. There is an opportunity for thermal imaging to be carried out from the street as a potential marketing tool. Thermal image cameras are cost effective pieces of equipment and relatively easy to use. More affordable simple hand-held cameras now available for a few hundred pounds which are ideal for installers to use to look for places where heat is being lost from a house, especially useful as a quality inspection tool before render finishes or cladding are applied to external wall insulation. However useful a thermal camera is, if it is not timed well with the project, its use in winter months may not allow render to be installed.

- **External wall insulation pull out test and additional tests**

A pull-out test is usually undertaken by the EWI manufacturer to ensure that the fixings will be retained by the wall substrate. The project team’s experience on this project and other retrofit projects, demonstrates a need for additional surveys, which can ascertain the following:

- Below ground drainage pipe location (when drainage adaptation is required due to EWI works)
- Roof and chimney condition (where chimneys are to be insulated)
- The structural condition of existing external walls (where EWI is to be installed)
- The structure and condition of eaves and wall-plates behind roof soffits for ventilation planning

These would not be required on every project but only where the existing conditions and potential proposed retrofit solutions dictate.

The pull out test used by EWI system suppliers to ascertain if the wall substrate is strong enough to hold the EWI fixings needs to be adapted to include a push in test to check the stability of the substrate to ensure it will not collapse inwards as the fixings are located in the wall as the EWI is installed. This needs a standardised industry wide test developed and enforced by the insulation trade bodies. Alternatively a less intrusive testing method could be developed which perhaps uses ultrasound.

The below ground drain survey would be undertaken to map the drain locations but could include a condition survey for added value. It is normally undertaken by a specialist and often a registered survey company, but could be potentially undertaken by a surveyor with the correct camera equipment. It may not be worthwhile for a retrofit installer to purchase the equipment due to the number of occasions it would be required. In this case a relationship with a drainage survey company which can respond quickly to survey needs should be established.

A small drone with a camera could be purchased by the retrofit installation company or its appointed surveying partner so that the surveyor can safely establish the condition of the chimney and any roof abutments to it. The drone could also be used to record the roof condition; if work is required this could be provided as an option over the retrofit work or as a trigger to encourage a customer to undertake retrofit work whilst the scaffold is erected for the roof work.

4.1.2. Design Process

We recommend that the current design process be improved by the production of a standard set of junction details for as many situations as can be considered for the range of house types and measures that will be installed.

These details would form part of the induction training for all installation teams and be kept as hard copies in the team welfare vehicle or preferably for reference on a tablet computer so that the information is live and current if any updates have been made. The operatives will get to know the details as they repeatedly install them and therefore there will be less need for design input and on-site checking of work at each dwelling thereby reducing costs. There will at times be details that are not in the standard detail pack, that are unique or require adapting from the standard one, and there needs to be a mechanism for validating these bespoke details and addition to the standard library. Over time the detail library will become more extensive. It is proposed that one of the following is included in the Retrofit Approach:

- The operations manager, who will manage multiple sites, is trained to read the detail drawings and has further training to enable them to make design decisions on site. This will reduce design decision times and the associated costs.
- A roving design and quality manager is appointed, who is ideally a technical architect or surveyor with quality/design management expertise, and he/she visits each site they are responsible for every day or every other day to check adherence to the details and make bespoke design decisions as they arise. This will reduce pre-handover snagging and defect repair costs, minimise design decision times and the associated costs and improve the overall installation quality.

4.2. Installation Process

The formation of a poly-competent team is intended to improve the installation process, from the householder, building owner and provider's perspectives. This demonstration project has shown that in many aspects this has been at least partially successful and that further future iterations will enhance and refine the Retrofit Approach.

4.2.1. Mobilisation

Key Issue: Delays to starting on site

Team: Late confirmation of team leader and team changes before starting on site.

Scaffold: Up to 10 days delay due to scaffold design, which was further extended due to scaffolding erection errors.

Material: Failure to pre-order materials with sufficient detail and lead-time.

Householder: Programming around householder schedules (due to holiday or work commitments).

Contract: Contractual delays from the client or contractor (not experienced on this project but has been experienced on other similar projects).

Complex co-ordination between multiple parties is a major obstacle for timely mobilisation. If a greater proportion of tasks can be achieved by the retrofit provider; there will be fewer opportunities for delay. With stable teams, operating at scale, availability will be clearer and capability and capacity to provide scaffolding / access systems with in-house resources will minimise the disruption experienced with external contractors.

Selecting products and materials from within a limited standard range will increase demand and volumes. This will lead to more reliable and minimal lead times, perhaps supported by stock held at a local depot.

Aligning multi-party contracts or sub-contractors is a cause of delay experienced on other retrofit projects. With a single retrofit entity dealing with the building owner this could be virtually eliminated.

Delays caused by the householder may increase costs and disrupt overall programmes and so clear communication of timing is valuable to avoid scheduling problems which undermine the reputation of retrofit delivery.

4.2.2. Labour time on site & for each task

Key Issues:

Process capability: Design solutions or tools which were not fit for purpose led to additional installation time in order to deliver the intended result.

Team capability: The poly-competent team, in some ways, was a compromise of skills. This could be substantially overcome through the development of processes designed for easy assembly.

Team work ethic / attitude: A range of excellent to poor was experienced on the demonstration properties and it has a major impact on productivity.

An example of design and process capability challenge is in achieving both insulation continuity and ventilation at the roof eaves. With limited existing space in the roof build up, ventilation products are difficult to install with the required insulation thickness, highlighting a need for new solutions.

The crucial challenge for retrofit works is to industrialise the installation process: Striving for easily repeatable tasks, delivered to a high standard, as a result of robust product and process design. EWI solutions need further development; particularly at interface details (window, eaves etc.). The more the process can be completed off-site (e.g. pre-finished panels ready to dry-fix), the greater the improvement in certainty of programme and costs.

With industrialised processes there is less dependence on operator skill and the focus can be put on identifying and developing individuals with the desired behaviours and aspirations to deliver a quality job. Further detail of industrialisation of retrofit processes is given in section 8.

4.2.3. Start and finish on site dates

Key Issues: Completion Delays

Programme over-run

- Delays due to weather conditions (particularly significant on RD1, RD27)
- Over-run due to the need to address technical and quality defects (RD5)

Snagging process

- Lack of staff or material made available for rectification of defects
- Delays to client surveyor review and sign off
- Delayed access to site for snagging based on resident availability

The goal is to remove weather dependency from the works and elimination of wet trades would be a big part of this; with the additional benefit of less disruption and risk of render splash damage to the property.

Snagging is endemic in construction, but with an industrial process of standard work it should be possible to minimise defects and get a right first time installation; rather than look to improve the rework process. The approach is designed to create quality assurance from within the retrofit installer base, rather than inspect and rectify quality control which comes at increased cost.

Quality control should be managed within the poly-competent team, overseen by the team leader. Daily informal inspections undertaken by the team leader should be coupled with weekly periodic inspections by an inspector external to the team, employed by the same company or a third party engaged by the installation company.

4.2.4. Installation programme

Once work starts on site there are five important factors which account for the vast majority of programme delay (priority order from the observation data):

- **Building condition uncertainty**
- **Weather dependency**
- **Task productivity**
- **Material supply and procurement**
- **Decision making processes**

Increasing confidence in the assessment of the existing building condition is the most critical variable to address in order to achieve a rapid and reliable programme: particularly on older properties. As a library of experience of house types, age and inspected condition develops; reliability of scope of works, and consequently, the delivery programme, will improve.

Industrialising products and processes and creating standard work for operators and back-office staff will help to optimise programme time. This is not a trivial task and will require investment in skills and capability for designers and co-ordinators as well as the poly-competent team.

The project installation programmes were developed with the team leaders to balance labour between tasks and minimise the need for external co-ordination between trades. Programmes were designed to be easily adapted to cope with the factors above; and all programmes needed multiple adjustments throughout the project.

4.2.5. Disruption levels

Minimising disruption to householders (and to some extent landlords) is an important part of the retrofit proposition. Although some disruption is inevitable, improving the customer experience will play an important part in accelerating the adoption of retrofit.

Key Issues: Level of Disruption

Loss of home utility:

- Internal space – **High**
- Restricted access to rooms/property - **Medium**
- Garden / driveway – **Low**

Uncertainty:

- Extended duration - **High**
- Unclear of works to be done - **Medium**
- Start delay – **Low**

Aesthetic:

- Impact internally - **High**
- Impact on access & garden - **Medium**
- Scaffolding during works - **Low**

To minimise the loss of home utility, rapid installation of internal solutions are needed and a focus on minimising the loss of access to any part of the property. This is achieved by improving logistics to minimise quantities of material on-site as well as minimising the creation of waste. Faster deployment of pre-cut solutions should be tested in future projects. Where there is significant internal work (as for RD1) there is little opportunity to avoid the temporary loss of utility.

With careful planning, standardised solutions and process, the uncertainty element could be managed to be low in each case. There would be a need to make clear to householders in older properties from the outset that there is typically an increased risk of finding problems with existing building fabric condition in order to better manage their expectations. Additional work due to hidden existing defects could be charged direct to the householder if they accept the installation team undertaking the work or homeowners in older homes could pay a price premium to cover the risk. In the latter approach, the retrofit installation company would typically lose money on some houses but gain on others so the premium would have to be set at a level which ensures that it is acceptable to customers and commercially benefits the company. Alternatively insurance based cover might be developed with a third party insurer to cover the risk; this is likely to need significant existing defects and condition data to establish credible and acceptable premiums.

Aesthetic impact is a matter of good design, attention to detail, combined with good logistics to remove waste daily and minimise material and plant left on site. For RD1 this was achieved to a limited extent (out of necessity) but there would be value in applying more extensively and making the *minimal materials on site* approach common on all retrofits.

The following table compares the assessed actual disruption with the estimated potential disruption if the above recommendations are implemented.

Table 1: Actual disruption and estimated potential disruption

	Assessed Actual Disruption				Estimated Potential			
	Utility	**Uncertainty**	**Aesthetic**	**Overall**	**Utility**	**Uncertainty**	**Aesthetic**	**Overall**
RD9	Medium	Medium	Medium	**Medium**	Low	Low	Low	**Low**
RD1	High	High	High	**High**	High	Low	Medium	**Medium**
RD5	Medium	High	Medium	**Medium**	Low	Low	Low	**Low**
RD27	High	Medium	Medium	**Medium**	Medium	Low	Low	**Low**

4.3. Supply Chain

The extent of the engagement with insulation manufacturer as the main material system supplier was focused predominantly on the technical performance of the products. The logistics and installation aspects were outside the insulation manufacturer team's remit. This was a missed opportunity to explore the potential for adapting solutions for easier installation and improving the supply process. In addition a depth of both cost and logistics transparency was lacking from the dataset, therefore potential costs at scale were assessed using other supply routes.

On-going discussions with other insulation and retrofit product manufacturers and suppliers have identified opportunities for, and interest in:

- Insulation optimisation software to enable installers to minimise material waste per elevation, by using photographic dimensioning techniques with insulation system requirement algorithms.
- System kitting in daily or two-day quantities: Linking manufactured products with other elements of the system on smaller quantity call-off to site.
- Integrated logistics where suppliers are both manufacturers and commercial distributors of insulation products. This provides greater transparency of costs and increased potential to collaborate across the supply chain to improve product and process.

4.3.1. Material Ordering

This has been the least developed aspect of the Retrofit Approach. Lengthy lead-times and 'non-standard' ordering / call off process proved to be a major challenge and required significant manual intervention from PRP, Total Flow, contractors and the suppliers' project teams. At this scale a 'manufacturer to site' logistics process is unfeasible and a consolidation point is needed for narrow residential streets (RD1).

Sunrise and sunset meetings with the installation team, led by the team leader and project team, reduced the need for 'blue-light' (unplanned but out of necessity) trips to local builders' merchants for material and tools. A van 'safety stock'[2] of key items linked with pre-packaged kit of parts for each retrofit measure and daily delivery would achieve the desired material flow.

[2] With a limited range of standard materials; it is viable for the retrofit team to hold extra quantities of material to cover excess usage, loss or damage. This is referred to as 'safety stock' – Root cause review of safety stock use should be part of the process.

4.3.2. Logistics

Key Issues:

Bulk Delivery: Vehicles, inappropriate for domestic delivery, making bulk drops added to the disruption of small domestic sites. Daily delivery of bulk materials using smaller vehicles (with waste removal) would have been ideal.

Consumables & Tools: Need to be part of standard van stock and replenished regularly. Before a daily review of plans, materials and tools was introduced; there were frequent 'blue light' trips to builders' merchants to get replacement drill bits etc.

Waste: Was unsightly and generally not recycled. Should be part of a full logistics & supply plan.

Welfare Van: Valuable for team meetings, food and hygiene facilities and small item storage.

Supply & Fit: (e.g. window specialists) Needs more precision in co-ordination than internal works. Suppliers should remove waste and old material from site immediately after installation as best practice.

The ideal scenario would be for a full kit of parts for one day's work to be delivered to site, or brought to site by the team in order to achieve a significant improvement in material flow, site tidiness, reduced material handling and damage.

4.3.3. Waste volumes / collections.

Four waste streams were identified:

Material offcuts – for external insulation this was significant in bulk and accounted for between 15% and 22% of insulation supplied, based on strict technical requirements for fixing patterns.

Packaging materials – Polythene, sealant tubes, render bags, plastic tubs, wooden pallets etc.

Parts to be replaced: Old guttering & pipework, window sills, PVC trims, fascias and soffits.

Excavation material: Predominantly soil, sand and bricks: In surprisingly large quantities.

Waste removal has a significant aesthetic impact, but also a potential cost impact. Unsegregated waste to landfill has a cost, but not yet enough to fully encourage segregation and recycling. Offcuts and excess material should be returned directly to the manufacturer, but this was not considered viable by the contractor / insulation manufacturer teams.

4.4. The Retrofit Approach – gaps and issues

4.4.1. Householder single point of contact

To give the householder confidence in the process and a positive customer retrofit journey, the Retrofit Approach proposes a single point of contact for the works.

For the demonstration properties this was not achieved because there was a need for up to three parties to be in contact with the resident:

The poly-competent team leader: Leading the works and managing the team

The project team observer: Not directly needing to liaise with the householder, but on occasion being asked to explain the design intent or process on behalf of the project. In the future this role should be integrated with the poly-competent team leader's role.

The Landlord's Surveyor: To confirm the Landlord's agreement to changes to the scope works and answer tenant queries (did not apply on RD27).

With the team-leader on site as works progressed, the approach worked well until a decision was needed or feedback was sought which was beyond their control, for example in the case of a tenant request for a change to the works. This is where some frustration ensued with the lack of availability of an over-stretched Landlord's team. Although not a major failure, the role and linkages to the landlord need formalising within the Retrofit Approach.

For the privately owned RD27 house there was no need for such escalation, but with the observer being much more familiar with the Retrofit Approach than the new team, there was a risk of blurring the relationship. The householder tended to ask the project team observer for updates on progress and queries rather than the team leader. Not a negative impact for the householder in this instance, but will need a clear process when the Retrofit Approach is delivered at scale, and highlights the need for the team leader to possess good resident-facing skills.

4.4.2. Standardised designs

With this project being a pilot and demonstration project the proposed design solutions had not been proven in advance and so needed some refinement on site.

Critical areas of the retrofit were the design details around joints and interfaces (e.g. Eaves, window reveals and drainage). With the emphasis on avoiding thermal bridges, the observer played a crucial role in identifying where installers either missed the necessity for a revised detail, or were willing to ignore a potential thermal bridge for expediency.

Despite very detailed pre-planning and design for the project, some details were developed on-site as the conditions were undetected at the time of survey or the proposed solutions found to be unsuitable. This led to decision delays and thinking time on site which slowed down the installation process. Standard details and processes will develop during future Retrofit Approach installations and a key learning point is the necessity for a robust process to:

- ensure that there is a readily available library of details,
- capture new successful solutions,
- set improved solutions as the current best practice standard,
- develop a decision tree to enable team leaders to rapidly identify the correct solution.

4.4.3. Standardised process

With observers on site to identify opportunities for improvement there were ideas which proved successful, but which were not routinely embedded for the next property. For example, steel base-track which acts as the carrier for insulation is very flexible and prone to bowing under the weight of insulation above. As an improvement, a length of timber was used as both a datum and a support on RD1 after the first lengths needed to be re-set. The same team worked on RD5 and would not have used the new standard process had they not been reminded by the observer. This demonstrates the need for simple, visual work instructions, known as 'One Point Lessons' for key processes and details to instantly capture, refine and share best practice.

4.4.4. Poly-competent team

The concept of the poly-competent team is at the core of the Retrofit Approach; incorporating all of the skills needed for the retrofit on site at all times to avoid co-ordination delays between trades. There was a general lack of commitment to the idea from the National Contractor. Although it put together a multi-skilled team (from two organisations), they were not willing to invest more than a day of the team's time in planning the programme delivery or coaching the team in methods of process improvement.

It was notable that on RD1 and RD5 in particular that the approach generally worked better than anticipated and the additional cost burden of a highly technically trained team-leader was invaluable to maintain progress. On RD27 the electrical capability was provided by a specialist outside the core team who came to fit the ventilation fans and adjust the lighting. This did not cause delay or frustration, but had there been a greater need for changes to external lighting and power; the lack of direct availability of skills would have caused delay.

The cost burden of a fully qualified electrician and gas fitter is still regarded as a disproportionate cost to the poly-competent team. One option to explore further, for delivery at scale, is to include a less skilled trainee or partially qualified electrician / gas fitter as part of the team and to get them to complete the works with final sign off by a 'roving' supervisor. This is an important option for further research.

4.4.5. Integrated Supply

For the demonstration properties, the goal of integrated supply, i.e. delivering kits of parts, in the correct quantities for a single day's work, was not successfully achieved as part of the Retrofit Approach.

With individual property retrofits, the gearing up of a logistics model for supply was not considered viable by the contractor and insulation system supplier. For most of the properties, materials were delivered in bulk, creating a challenge to unload rapidly (on occasion with oversized vehicles blocking street access) and find storage space on site. This led to considerable loss of garden utility for RD9, RD5 and RD27. In contrast, the RD1 site was very small with minimal storage space, other than the scaffold, and as a result the insulation supplier arranged for multiple deliveries of smaller quantities, called off from a local depot the day before. This was a much better approach and could have been improved further by the integration of other materials beyond insulation and including consumables, hand tools and the removal of waste.

For waste removal, the retrofit contractor for the three houses in London provided a weekly collection van which covered multiple sites across the entire M25 area, requiring many hours of driving per day. For a single site activity this is a cost and environmental burden, highlighting the need for a degree of scale within a locality. Without smaller, more regular deliveries (or material being brought by the team) the customer retrofit journey will be degraded. The clutter of gardens caused concern for two householders and would be more likely to generate complaints for properties with well-tended gardens which are likely to suffer from material storage to a greater degree than the grassed / paved properties in the four demonstration properties.

4.4.6. Technical Solution

All the required technical solutions were resolved either before the works started on site or during the works where designs had to be evolved due to previously unknown conditions. Where there was a shortcoming is in the ability to install the proposed design solution around windows which was an insulated removable board which would ensure that the rendered EWI is not damaged by future window replacement. The limitation is in the ability to install a sufficient thickness of insulated reveal to reduce the risk of a cold bridge, without impinging on the sightlines or opening of the window. Thinner insulation products are becoming more available to provide a better solution to this problem in the future.

Design: Despite the highly detailed planning and survey of the properties, there was a still a need for design change and iteration on site. This could be greatly reduced following the development of a comprehensive library of design details. In the meantime, the ability to respond rapidly to site queries and design is required. This could be in the form of a 'floating' local design specialist to attend site as needed (which incurs a significant cost burden unless spread across a large number of teams and projects). An alternative is to use technology for site staff to interact with office based designers with data-links and video.

Survey process: There are gaps in the survey detail from two areas in particular: (i) Drainage – identifying pipe runs (particularly under concrete) to plan relocation of soil stacks. (ii) Roof and eaves condition – challenging to identify remedial needs from ground level. New technologies including ground penetrating radar and drones need to be investigated as possible solutions for obtaining this data.

Integrated supply: Householder concerns about disruption from on-site storage of material and waste demonstrates the need for integrated logistics and supply. This is compounded by the delays to programme from lack of timely delivery. The requirement must be to establish a mechanism by which material is delivered / collected daily or at least three times per week.

Disproportionate costs: In dealing with whole house retrofit, the Retrofit Approach aims to deal with all significant sources of heat loss. From the demonstration properties it is apparent that some measures attract disproportionately high costs, including:

- **Chimney works:** Requiring additional scaffold with a doubling of cost.
- **Floor insulation (RetroPlus[TM]):** Both suspended and solid floor insulation options require significant cost unless the prototype robotic insulation system cost can be dramatically reduced.

These measures cost more than the energy they save over their lifetime, but are necessary parts of a whole house solution (to avoid cold spots and mould). This should act as a driver for further innovation to achieve a target cost and performance; not to abandon the idea as too costly.

Programme overrun: All householders experienced delays and confirmed the overriding desirability of a 10 or even 15 day programme rather than the 24 – 46 working days experienced. (As a result of the RD5 rebuild, the residents coped with scaffolding for 16 weeks).
This emphasises a requirement for a more predictable programme, including an ability to increase labour onsite to recover time delays.

Quality sign off: All properties had protracted snagging rectification periods which frustrated householders due to further delay and on-going works in their home. The quality handover process is not currently an integral part of the Retrofit Approach and needs to be developed further to improve the proposition.

4.5. Barriers

Householder funding and investment: Energy performance improvement is being squeezed from three perspectives: UK Government funding for energy improvement has been withdrawn from all but the most fuel poor households; In the social housing sector, Registered Providers face significant income cuts over the next four years and maintenance budgets are being squeezed as a result; and in parallel, recovery from the dramatic downturn in the private Repair, Maintenance and Improvement (RMI) market in 2008 is greatly lagging the upturn in the housing sale market (2015, Financial Times). However, the current market is £14bn and a growing current focus is on property value adding investment which, from our research, excludes retrofit as a valued home improvement.

Training and skills: Construction industry funding for training has been led by CITB through a levy system which is in a state of flux due to changes to its funding and remit. In parallel, the Centre of Refurbishment Excellence (CoRE) has closed and the Retrofit Academy is no longer taking bookings for courses. This leaves the sector lacking a clear path for upskilling and organisations will need to fund their own training and collaborate or develop capability from within.

Energy performance certificates (EPCs): The assessment of a home's energy performance is assessed by a very simplistic SAP assessment tool which assesses insulation levels and predicts heat loss. Houses retrofitted according to the Retrofit Approach will score well on the A-G ratings, but the ranking will not account for the superior performance resulting from improved air-tightness and reduced thermal bridging and so underrate the post-retrofit score. In such circumstances householders will rightly ask why they should bother to invest. As such the EPC calculation method for retrofitted homes should use a full SAP calculation and not the standard reduced SAP method. Alternatively the smart meter data could be used to provide energy performance data for analysis and interpretation of newly developed software.

4.6. Confirmed benefits

This section briefly summarises the benefits of the Retrofit Approach revealed with the works at the demonstration properties.

Consistent Team and Single Point of Contact: All residents valued the consistent team rather than a series of trade specialists. They appreciated having a known team leader on-site for concerns and queries, although with a Project Team observer there was not the complete clarity of a single point of contact.

Poly-competent team: From a process perspective it is clear that there is value in including electrical and gas capability within the team to minimise the need for external co-ordination of staff. However, on RD27 there was very limited gas / electrical work and the lack of embedded capability did not cause a problem. This leads to a potential refinement of the model where the team composition can flex with the complexity of the retrofit.

4 Person team: All householders recognised the value of a small and consistent team enabling them to build rapport with individuals. However, with the programme delays experienced; they would have been happy with a larger team to achieve an earlier finish.

Whole house solution: The whole house approach, which includes draught-proofing to reduce air permeability, is very beneficial - two households had previously had replacement windows installed and continued to experience draughts until the whole house Retrofit Approach tackled air leakage.

5. Market Opportunities for the Retrofit Approach and Alternative CO_2 reduction strategies

This section summarises the successes and challenges experienced across the four demonstration properties and explores the options to deliver both the Retrofit Approach and the alternative approaches to reducing CO_2 emissions.

5.1. Sector Market Opportunities

It is clear that at the current target cost, whole house retrofit will not payback in a period that is acceptable to customers through energy bill savings alone. Therefore, there have to be other reasons for the customer undertaking retrofit. In this section we explore the value drivers for the three distinct market sectors:

- Owner Occupiers
- Social Housing
- Private Rented Sector

5.1.1. Creating an Owner Occupier market for retrofit

For owner occupiers, trigger points for undertaking retrofit maybe one or a combination of the following:

- Improving the external appearance of the home
- Improving internal comfort and air quality
- Minimising condensation and mould risks
- Repairs to the existing external fabric
- Internal layout changes/garage conversion
- Extension or loft conversion
- Renewal of roof coverings
- Renewal of roof soffit/fascia
- New kitchen or bathroom
- Upgrades at point of purchase
- Renewal or upgrade of the heating system
- Addressing affordable warmth concerns
- Change in family circumstances or income

There is a small and growing market for retrofit at the point of purchase of a house, particularly when a home needs modernising to meet the needs of modern day living.

Offering retrofit work alongside modernisation services via estate agents (high street or internet) or the mortgage surveyors (indirectly or directly) may provide business growth, especially in affluent areas where purchasers may have the funds to do the work and the desire to improve the quality of the house and its environmental performance. It seems that houses built in the decades between 1950 and 1980 are those which purchasers and current occupiers wish to upgrade due to their outdated external appearance and internal room arrangements. This often includes new windows and external doors and rendering over brick walls to provide a more contemporary appearance; this provides an obvious opportunity to insulate and reduce the air permeability of the house. Ventilation solutions should always be offered alongside the thermal improvement and air permeability reduction and the customer made aware why ventilation forms an important part of the retrofit package.

Houses which were built before 1950, particularly those from the Georgian period and some from the Victorian and Edwardian periods, have typically larger rooms and higher ceilings and architecturally more attractive facades. Purchasers and current occupiers wish less to upgrade the external appearance and internal layout (even if planning policy would allow) as the houses are more desirable and suitable for modern day living. For such properties retrofit solutions will need to be more focused on sympathetic upgrade of desirable features or retrofit solutions which do not impact on the heritage features or overall appearance of the house. Homes built in the 1980's and 1990's are better insulated than those from previous eras and are less likely to have major renewal or upgrade works to elements such as roofs due to the age of the home and the lifecycle of those elements. However, windows/external doors, roof soffit/fascia and driveways are often replaced as they are reaching their end of life. Other works undertaken on homes from this era are the conversion of the garage, the addition of conservatories and rear single storey extensions. Each offers to a lesser or greater extent the opportunity to be combined with thermal improvements to the building fabric but more likely to be an elemental improvement rather than to the whole house. Householders do not typically want to change the appearance of the house, partly as it is often situated in an estate and the concern is that any change to the overall appearance may devalue the house, either financially or from a desirability perspective.

In our opinion the retrofit market can be created through:

- Offering thermal and ventilation improvements alongside major upgrade works, particularly targeted at homes built between 1950 and 1980. Relationships with estate agents and surveyors may help to build this work stream.
- Offering retrofit installation services alongside other renewal works such as windows and roof soffit/fascia replacement.
- Encouraging dwelling downsizing via the provision of high quality local retirement housing to enable larger houses to be vacated and allow modernisation and thermal improvement work to be undertaken. Relationships with retirement living/care providers may help to build this work stream.
- Offering finance for retrofit work, likely attached to the mortgage for its remaining duration, which is paid back through energy bill savings.
- The use of planning payments (community infrastructure levy, carbon offset payments etc.) made to local authorities, to fund area-wide retrofit delivery.

The marketing and branding of retrofit will be key to generating a market. Owners of private homes do not typically purchase insulation or ventilation products because:

- The products are not desirable, or
- Lack of knowledge of the benefits of insulation, or
- Not knowing where to get appropriate advice about what to install

A marketing campaign which focuses on the benefits of retrofit and uses terminology which is better understood and appreciated by the potential customer must be considered. Perhaps the word's retrofit and insulation should not appear in the marketing material at all but terms such as internal comfort levels, savings meaning more money in your pocket, health & wellbeing of you and your family, improved lighting levels, appearance of your home, smart technologies for easy control etc. should be used in marketing approaches to sell the wider benefits of retrofit to householders, A study is needed to understand how retrofit can be better marketed to householders.

5.1.2. Building the Social Housing market for retrofit

Social housing providers face many of the same trigger points and obstacles to retrofit as Owner Occupiers. This section focuses on the distinctive characteristics of the sector.

Priority trigger-points are:

Voids: The opportunity to link retrofit with a vacated property with a change of tenant. Time is of the essence to house families on the waiting list and regain income for the landlord. If the Retrofit Approach can be delivered cost-effectively in as little time as a traditional void refurbishment it would be an ideal opportunity to refine the technical solutions.

Window replacement: is regularly scheduled by Registered Providers and creates a rolling programme across their stock. If the Retrofit Approach demonstrates significant improvement for marginal additional cost it will generate some scale of retrofit demand.

Improved value for money in refurbishment and reduced future maintenance costs are key drivers for social landlords. Heating systems and plumbing are their most significant maintenance cost burden and tailoring retrofit to cost-effectively include, or align with, installation of new heating (possibly communal or district heating) will provide an attractive offering.

Social housing is generally constructed to a higher standard and is better maintained than the private sector stock. This reduces cost uncertainty due to building condition and the need for remedial works. However this project has shown that is not always the case and retrofit programmes actually offer landlords an opportunity to gather more detailed information about houses than asset management records contain and undertake any required remedial works alongside the planned retrofit work.

The health and wellbeing of tenants is a priority in the social sector which has a high proportion of vulnerable and disabled households. If the Retrofit Approach is confirmed as creating 'healthier' buildings by making them warmer whilst controlling ventilation it will be even more appealing to Registered Providers. High quality whole house retrofit with ventilation will reduce the risk of mould and condensation when considered against single measure retrofit such as cavity wall insulation which does not include ventilation measures or deal with thermal heat loss at the houses corners and junctions (thermal bridging).

As charitable or public sector organisations, Registered Providers have a social purpose and would be attracted to a refurbishment model which provides employment to local residents rather than bringing in national contractors. One aspect of the Retrofit Approach is to create industrial processes for which skills and capability can be quickly developed rather than requiring time served craft skills.

With the funding challenges in this sector it will be appealing for Registered Providers to be able to generate additional income from offering their retrofit solutions to the private sector. This helps to generate scale for their solution as well as additional revenue. This could potentially be achieved by leveraging their brands as an often trusted partner in the community and benefitting from commission or margin on future works.

5.1.3. Creating the Private Rented Sector market for retrofit

The Private Rented Sector (PRS) can be broadly categorised into two distinct groups:

- Amateur landlords currently own the bulk of the PRS stock 71%[3], but they typically rent one or two properties as an investment rather than as a commercial business. These landlords tend to behave in a similar manner to Owner Occupiers, whilst meeting the requirements of regulation, and their lenders if applicable.
- Professional landlords (company or 'other organisation') account for the remaining 29% of PRS properties and represent the fastest growing sector of the housing market. New professional institutions are developing new residences on a 'build to rent basis' these are led by both UK and overseas pension funds and insurance companies.

Landlords will be required to improve homes to meet Energy Efficiency Regulations which require properties to achieve an EPC rating of at least E on new tenancies from 2018 and also make energy efficiency improvements where reasonably requested by a tenant; although there is no funding (other than the tenant or landlords own investment) to pay for it.

Institutional professional landlords are looking to invest in long term assets and manage them as a reliable income stream. They require predictable operating costs and a retrofit proposition which protects the value of their asset, whilst making it more attractive to tenants (or at a higher rent); to make retrofit an investable proposition. Current focus for some is as an arm's length investor buying the properties from Registered Providers and leasing back. However the project team have initiated discussions to explore the value of retrofit to protect assets and the concept is of interest to at least two large pension companies

[3] https://www.gov.uk/government/statistics/private-landlords-survey-2010

5.2. Alternative Approaches

There may be credible alternative approaches to reducing the UK's CO_2 emissions other than whole house retrofit undertaken with residents in situ. These include:

1) Do not retrofit homes – focus efforts on grid decarbonisation
2) Demolish existing homes and replace with new homes
3) Retrofit homes on resident change (sale or new tenants)
4) Retrofit homes whilst residents are on holiday (Vacation Retrofit)

Demolition and Renewal - Where existing houses are in a poor condition due to the original build quality or inadequate maintenance, it may be more time, quality and cost effective in the long term to demolish the house and replace it. Our work to date shows that homes built immediately after the Second World War are often of inadequate original construction and now have structural and fabric defects. Homes constructed in this era may be ones to consider for renewal. It is estimated that the cost to replace a 3 bedroom semi-detached home is approximately £120,000 (costs will differ regionally) but the target cost should be less than £80,000 which assumes a £50,000-60,000 cost for an off-site manufactured home. It is understood that under current VAT rulings, the replacement home would be exempt from VAT.

The replacement home could be built offsite in factory conditions to ensure quality and thermal performance and erected in less than two days on site. The whole process including demolition, installation of new lightweight foundations and ground floor, connection of services and erection of the new house could be achieved in less than two weeks. This solution could not be used for terrace or semi-detached houses without the full terrace or adjoining semi-detached house being also demolished and replaced. Ownership matters would therefore have to be considered. The thermal performance including air permeability of the new house could be much greater than the retrofitted house, requiring very little heat energy to keep the home comfortable in colder months. The internal layout of the new home would meet modern day living standards and regulations, which the existing home may not.

Retrofit on Vacant Homes - Undertaking retrofit on vacant homes, either at the point of sale or rent would speed up the installation process as the house is empty (no residents or furniture to hinder access) and the interior at least does not have to be fully tidied at the end of every day. This would reduce the overall costs by the very least, the cost of the possession storage and removal and also likely an amount associated with the time saving, calculated to be 3-5% of the overall installation time of external works. Considerably more time could be saved if internal wall insulation is being installed and a potential overall cost saving of £3,000 based on the cost per house in this demonstration project. If a driveway exists, it can be used for materials storage and waste storage without hindering parking of the resident's vehicles.

A vacant home means the required time to communicate with residents is nil or if considering a house where the residents are on holiday, it is much reduced in comparison to an occupied house. This reduction in customer engagement will reduce the installation team's overheads by an estimated £500.00 per home. The approach to retrofitting whilst the residents are on holiday would require complete clarity of the works and their impact, to avoid the risk of disputes on the householders' return.

6. Commercial Models for the Retrofit Approach

This section takes delivery insight from the demonstration properties and aligns it with market opportunities for the Retrofit Approach as a new commercial proposition. Potential commercial models are reviewed and a template for a consortium approach to retrofit delivery at scale is proposed.

6.1. Value Chain Map

The following Value Chain Map (Figure 1) shows the current landscape for the repair and improvement of domestic properties. Currently the bulk of the market is in Owner Occupied properties (63%[4]) and Private rented (20% and growing), of which much is owned by individual 'amateur' landlords. For these groups, refurbishment and retrofit is likely to be provided by a local builder or home improvement chain, with a lack of integration in terms of design expertise, supply chain and logistics,

For Registered Providers and commercial private rent sector landlords, refurbishment is more likely to be delivered through specialist facilities management contractors or other framework suppliers, although smaller local firms are not uncommon. This gives a mechanism to engage with specialist design resource and integrate with product suppliers, but frequently this is not seen as necessary.

This leads to a value chain which is transaction based and at times adversarial between client, designers and installers. Product and system manufacturers or distribution / logistics to site companies are not currently seen as important to successful retrofit delivery. The closer integration of design, supply chain, installers and property owners will enable improved alignment of design, installation, logistics, manufacturing and operational efforts to achieve better performance, cost, time and quality outcomes.

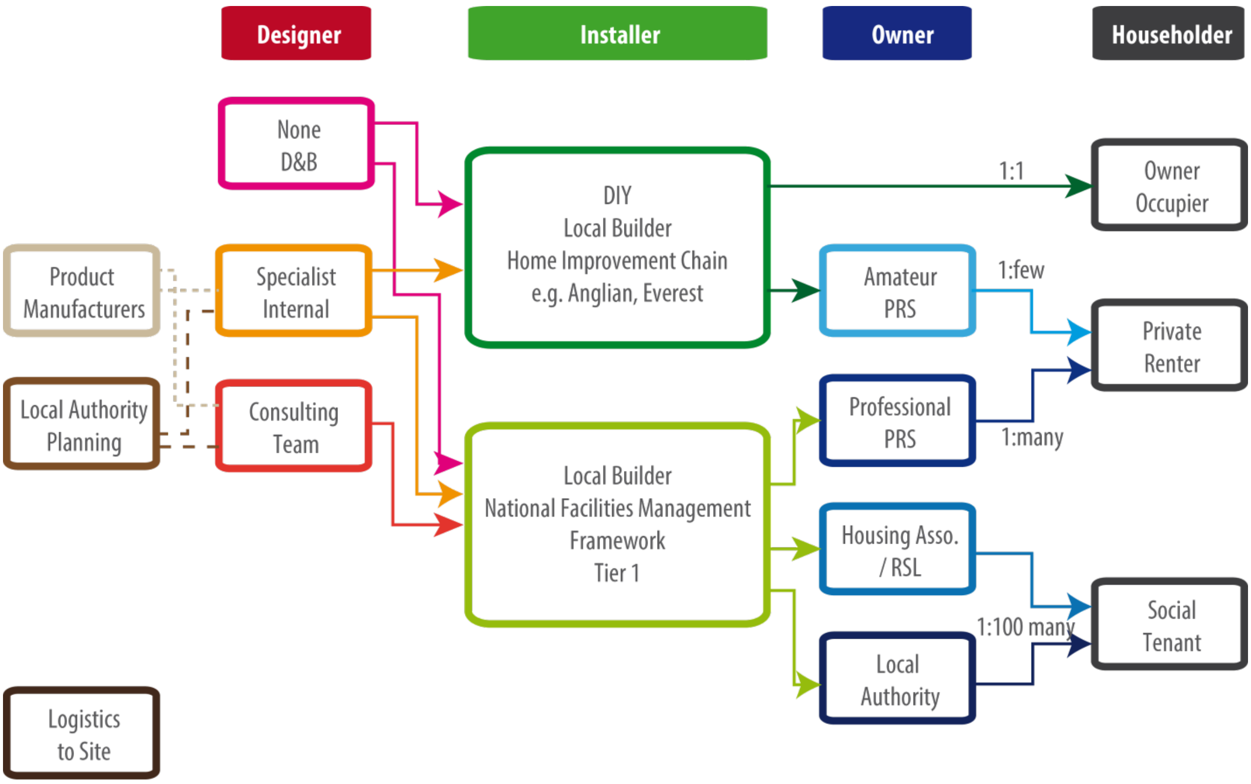

Figure 1: Value Chain Map

Alternative approaches to achieving this are explored in the commercial models section below.

[4] English Housing Survey, Housing Stock Report, 2014-15, DCLG, 2016

6.2. Commercial models

In this section, alternative commercial and delivery models have been reviewed to assess the options most likely to succeed for retrofit delivery at scale. The following are compared below:

- National Contractor – As used for RD9, RD1 & RD5
- Smaller Regional Contractor – As used for RD27
- Independent Team
- National Franchise
- Direct Labour Organisation

6.2.1. National Contractor Model

Direct experience within the demonstration project yields the following strengths, weaknesses and opportunities for the national contractor approach.

Strengths:
Scale: Security of a large group which is branded, financially stable and proven.
Buying power: Purchasing in volume with material suppliers to negotiate low prices.
Resources to invest in Research and Development – although not a core part of the business.
Experienced in construction, refurbishment and facilities management.

Weaknesses:
Co-ordinator of sub-contract trades rather than an employer / developer of skills / capability.
Multiple layers of margin and overhead, leading to high hourly rates, material mark-up and overhead.
Operate in adversarial contracting markets with low margins; leading to challenging commercial negotiations when problems arise.
Experienced in large, long-term contracts which do not fit with individual domestic properties; unless individual homes for a Registered Provider.
Bureaucratic and risk averse; both commercially and technically.
Pricing approach is cost plus rather than a design for affordability or target cost.

Opportunities:
To overcome the weaknesses would require a significant change in the contractors' operating model. This could be achieved by setting up a separate business unit as a pilot to create an operation with directly employed staff and a development programme to address skills and develop the poly-competent team model. Commercial challenges may be addressed at the business unit level. However, at present this model does not appear to fit with the business plan of contractors.

6.2.2. Smaller Regional Contractor

The direct experience with the regional contractor at RD27, led to the following assessment of the small regional contractor commercial delivery model.

Strengths:
Lower costs and pricing from reduced overhead.
Appetite for innovation and collaboration to secure growth in emerging niche markets.
Agility of decision making with fewer levels of authority than national contractors.
Ability to respond to both repeat contracts (with Registered Providers) and direct to householder.
Local focus to leverage scale, albeit in a reduced area.

Weaknesses:
Scale: Smaller organisations are less robust to cope with market fluctuations or problem contracts.
Specialist trades sub-contracted leading to challenges of co-ordination on a short programme.
Investment: Limited financial resources to invest in training and enabling assets (e.g. Welfare Van).
Limited buying power to achieve the highest levels of material discount.

Opportunities:
Small regional contractors have the potential to develop a reputation for quality and service to build a customer base and scale. There will be a need to link with design specialists to develop robust product offering and also improve operator capability: This needs investment of time and funds. Their scale may not warrant the greatest material discounts but, by partnering with system providers, there will be potential to collaborate and develop a least cost of supply model through which both organisations will benefit.

As an example of this model; the Mark Group developed from a regional contractor, in renewables and insulation, from Leicestershire to create national specialist employing 1200 people. The employed team model was predicated on consistent market demand which collapsed with cuts to the Feed in Tariff and withdrawal of insulation initiatives like the Green Deal Home Improvement Fund. The business was put into administration in 2015 with the loss of 1200 jobs. Job-Worth-Doing is currently operating in this area with a growing presence, but with challenging market conditions.

6.2.3. Independent Team

Small, independent EWI teams where established with the introduction of the Green Deal Home Improvement Fund. These teams operated both as direct to consumer installers and as suppliers to larger commercial organisations.

Strengths:
Lowest overheads.
Direct contact with the business owner.
Adaptable to Retrofit process requirements.

Weaknesses:
Market credibility: Without a track-record or recognised accreditation clients and consumers will be taking a risk on an independent team.
Difficult to scale without the dilution of capability.
Dependent on cash-flow and consistent workloads.
Very limited technical back-up without a design / supply partner.
Credit based buying power and may pay close to list price for materials.
Difficult to invest time to increase skills unless during a paid contract.
Investment: Unlikely to be able to invest in training and enabling assets.

Opportunities:
An independent team with an ambition to deliver high quality Retrofit could be a cost-effective solution for delivering at a small scale. To be successful in the market, the team will need both design and supply chain support.

Collaboration with a branded commercial entity could be a valuable way to generate new business, if the team hasn't established a positive reputation in the sector. This may encourage independent teams to operate as a supplier to Contractors, Specialists, Franchisees or Local Authorities in the other models.

6.2.4. National Franchise

A franchised commercial model would involve a franchisor developing common processes and standards for retrofit delivery (e.g. brand, marketing, design, insurance, approved suppliers, certification). The model enables delivery capacity to scale, without the increased risk of employing large numbers of staff.

Strengths:
Highly scalable; particularly in a growing market.
Less investment required to create a market presence.
Local franchisees often have direct links to their community.
Committed / entrepreneurial installation teams.

Weaknesses:
Requires demonstrably viable business model to attract partners and franchisees.

Opportunities:
Potential for the franchisor to be one, or a combination, of:

- Material manufacturer: Providing a route to market for retrofit aligned products.
- Architect / Designer: Creating a product based design solution, leveraging an existing brand.
- Building products distributor: Aligning retrofit products with installers close to depots.
- Energy company: To address their carbon reduction obligations.
- Consumer brand: To align with sustainable corporate strategy.

A consortium approach could provide a powerful alignment of brands to give confidence to the market and provide the scale and investment to establish capability to deliver at scale rapidly.
The consortium approach could be analogous to: Dell Laptops: Intel Inside: Running Windows 10.
The boundaries of the franchise model may be set at a number of different points. The franchisee providing installation labour only, or taking additional responsibility for: Sales, marketing, design, material control, etc. This model is explored further in section 6.3.

6.2.5. Direct Labour Organisation (DLO)

Previously Local Authorities (LAs) and Registered Providers (RPs) with stocks of social housing used directly employed maintenance and minor works teams to maintain, repair and upgrade properties. For the last twenty five years the works departments have tended to be out-sourced to Facilities Management (FM) companies, in parallel with setting up of Arms' Length Management Organisations (ALMOs), in order to remove the burden of internal costs and drive efficiencies. The approach has come full circle; RP's & LA's, dissatisfied with current costs and service of commercial contractors, are beginning to in-source construction work.

Strengths:
Not for profit organisations with significantly lower corporate overhead for a similar cost base.
An internal market for their own housing, with potential to offer services to owner occupiers.
Generally driving for the high standards of sustainability which are core to the Retrofit Approach.
Tenant / householder focused to provide good service and value for money to residents.
A strong social purpose and a drive to upskill and enable residents to find local work.

Weaknesses:
Risk averse for new solutions, models and investment; slow to decide and implement changes.
Internal technical capability has diminished in many years of out-sourced maintenance and works.

Opportunities:
The revised Rent Formula (2015) has left social housing providers with a gap in finances which will continue to widen until 2020. This has led many to look at innovative ways to innovate and close their funding gap with new revenue streams. Some are exploring low-risk opportunities to build maintenance capability, or partner with organisations that share their values and social concern.

Housing Associations, RPs and LAs have admitted that the thought of setting up a Direct Labour Organisation (DLO) is a daunting task. Options for building on the experience of others are attractive solutions for refurbishment including retrofit. In discussion with one existing DLO and three RPs considering the idea; there was genuine interest in partnering with organisations able to support the development of new capability for a Retrofit DLO. The idea of a "Retrofit DLO in a Box" as a template for a new DLO, including commercial templates, design solutions, supply chain and capability to develop skills in staff was seen an attractive offering once proven, better still if adaptable to include wider benefits.

6.3. Markets, Franchise & Consortium Model Details

The supply chain diagram in Figure 2 shows an indicative model of key elements of the retrofit value chain. The following are players in this model:

Product manufacturers who supply a distribution or consolidation centre, where materials are cut to size and kitted to specific orders.

Materials are delivered to site every 1 or 2 days on the mid-sized vehicle's regular route. Waste material is also collected at this time and recycled directly (ideally back to the manufacturer).

The poly-competent team and building surveyor provide the installation capability.

Design support is provided by a design company employed by the installation company.

Single dwelling owner occupiers and multi-property social or private landlords are served by the alternative models described below.

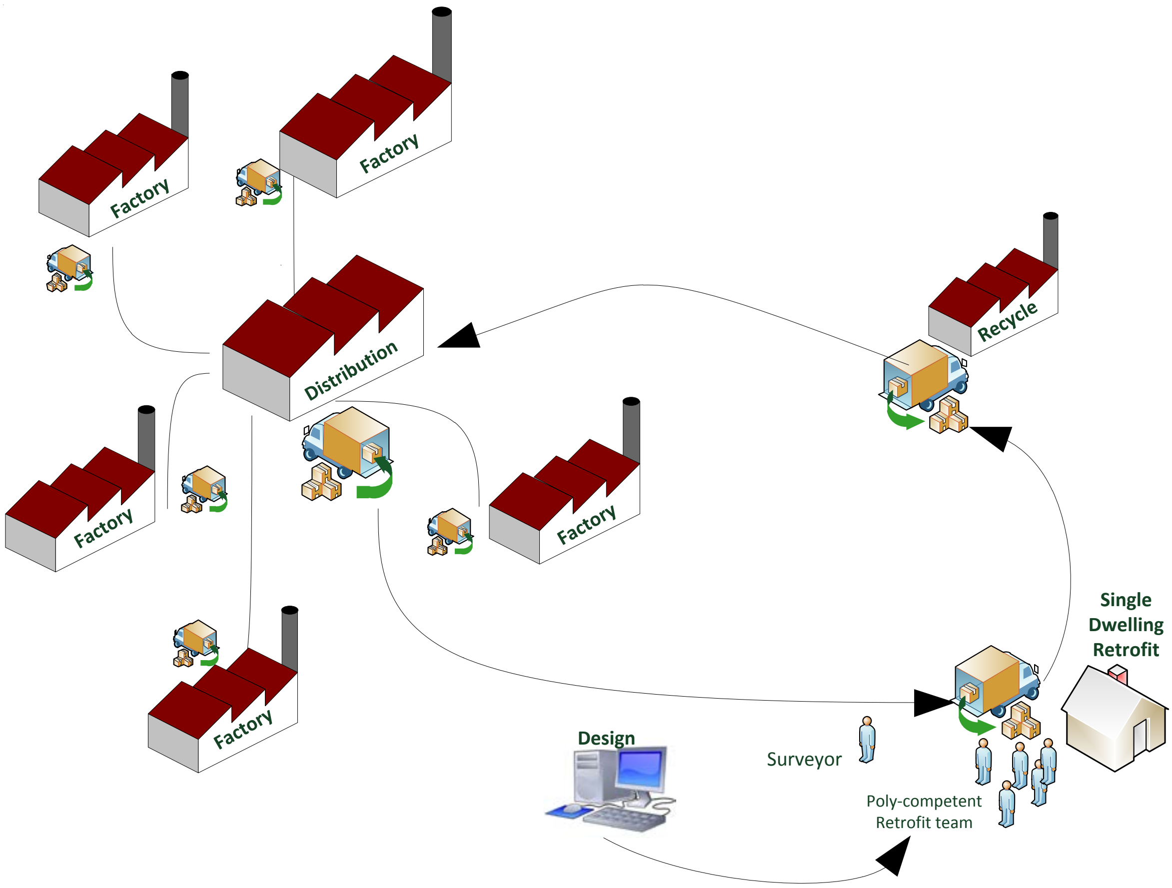

Figure 2: Supply Chain Model

Ownership, organisational boundaries, commercial relationships and collaboration in this structure can take many forms and the merits of three alternative approaches are discussed as follows.

In Figure 3 the shaded areas show options for organisational boundaries across the supply chain and the first example shows an integrated manufacturer / distributor that has set up a franchise model. The franchisee is the poly-competent team (or a cluster of teams for scale). In this instance the design capability is within the team, but this could also be an offering from the franchise. This model is straightforward, but requires a significant strategic investment from the manufacturer / distributor to launch and scale.

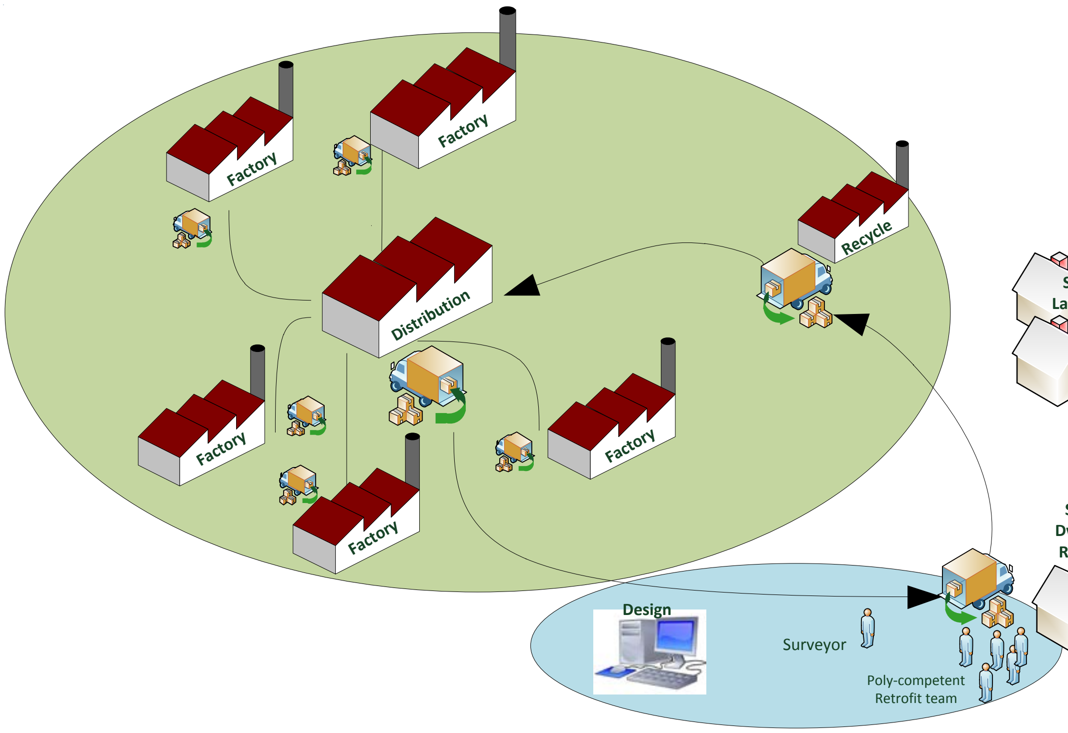

Figure 3.1: Manufacturer & Distributor Franchise

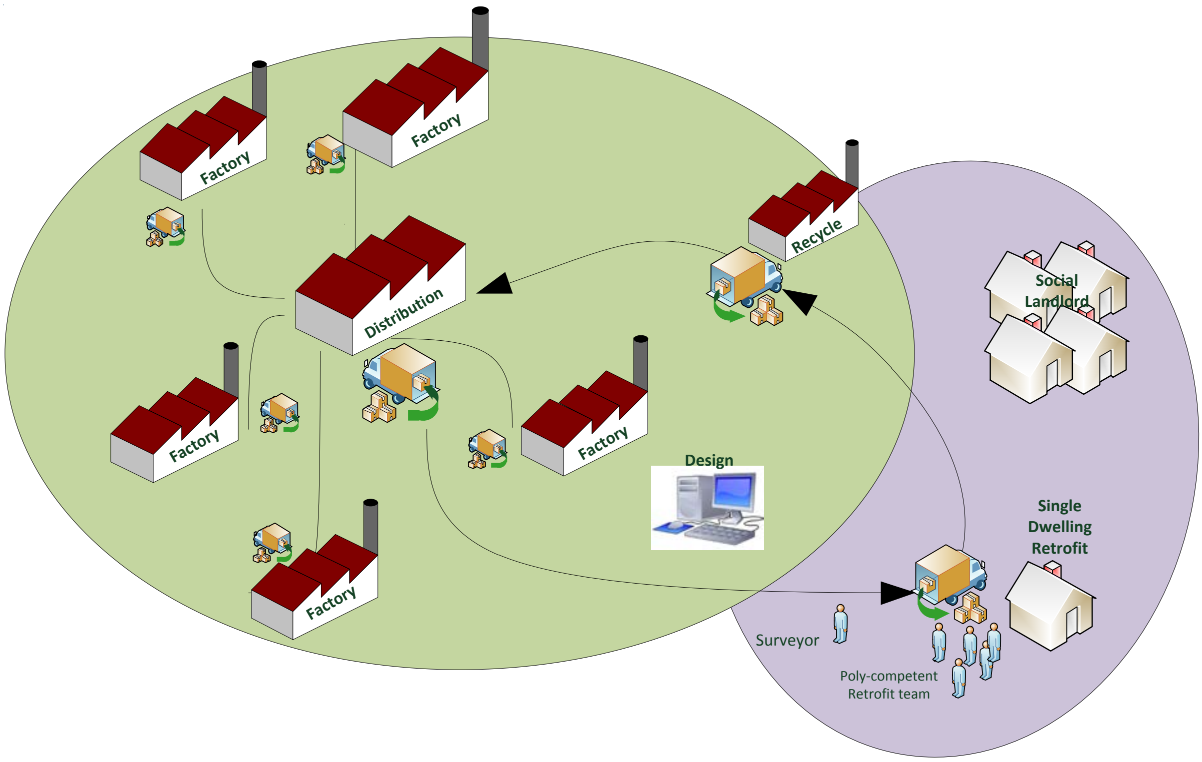

Figure 3.2: Distributor and Registered Provider Partnership

The second example in Figure 3 shows a partnership between a manufacturer / distributor and a Registered Provider. This has the advantage of generating initial scale for Retrofit delivery from the landlord's stock and also the opportunity to extend to the private sector. The team and surveyor are shown as being part of the RP's staff.

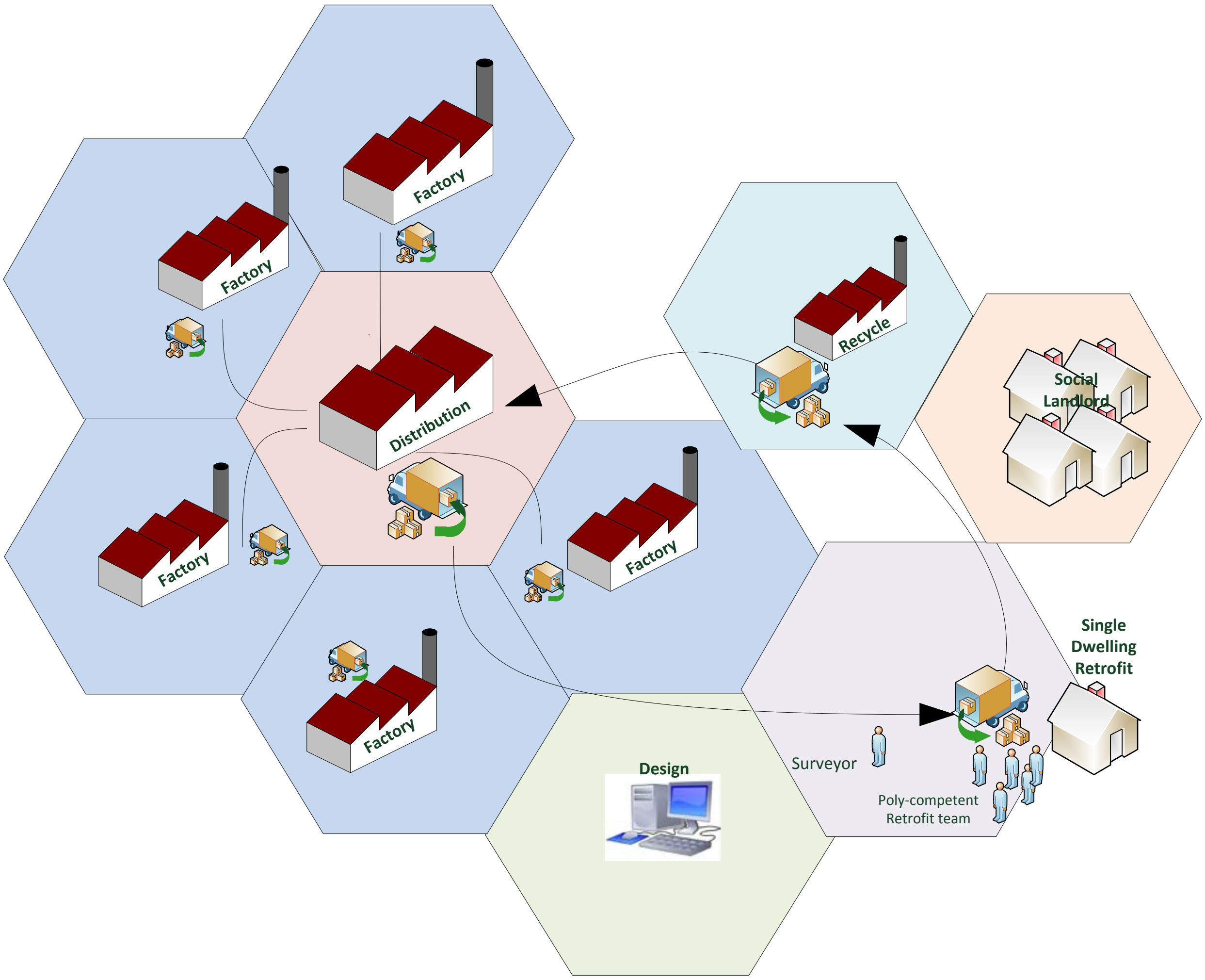

Figure 4: Consortium Approach

In Figure 4 the model is a consortium of organisations that have come together to collaborate and develop an end to end retrofit offering from product design and manufacture, through distribution to design, install and property management. Brands from outside this direct value chain may also be included to give consumer credibility (e.g. M&S Retrofit supporting Plan A), or energy suppliers to build their reputation for sustainability (e.g. Ecotricity Retrofit helping you use less of our green energy).

The boundaries and consortium involvement can be varied to any extent and it is important to avoid unnecessary complexity. However, there may be value in a few market facing brands to give consumers confidence that the retrofit offer is credible and has integrity; rather than the 'White Label' branding of mediocre services. Developing the computer analogy used earlier, a market facing consortium might be: Virgin Retrofit, insulated by Celotex powered by British Gas Home Care.

7. How to Achieve Commercial Viability of the Retrofit Approach

7.1. Cost analysis

Detailed analysis is presented in section 5 of Report 1 where the evolution of costs, for each property, is presented across six assessments:

- Costs proposed in the ETI OTEoEH Project in 2012[5]
- Business as Usual EWI costs from 2014
- Project budget costs from the national contractor in the demonstration trial from 2014
- Project Out-turn costs from 2015/16
- Expected Costs assessed for the Retrofit Approach at the end of Stage 1 (2014)
- Revised Expected Costs for Retrofit Approach since the completion of the 4 properties (current study)

The revised costs for the Retrofit Approach are developed bottom-up from:

Poly Competent Team Labour rates

A target programme of:

- o 2 weeks (10 working days) for a typical property – RetroFix™ standard
- o 3 weeks (15 working days) for RetroPlus™ enhanced (triple glazed)

Material costs are set from project spend, supplier discussions and wider research.

Site costs set from project costs and research: welfare, plant, scaffold, site management.

Project overheads set from research: survey, building control, design administration, fixed profit.

7.1.1. Target Cost

Previous research in the ETI OTEoEH project identified the threshold of £10,000 as a psychological home improvement watershed for the customer. A price below this figure is seen as affordable to a considerable population of householders. Above £10,000 is seen as a major refurbishment with a more limited market, unless it is seen as a way to add value to the property (e.g. conservatory). These findings were reinforced by Home Improvement businesses that experienced customers more willing to invest £7,000 (for example) in two stages rather than to fund an initial £12,000 project.

This watershed is particularly important for owner occupiers and small scale private landlords.

Even at the £10,000 level the payback on investment is marginal: with typical energy bills it is likely to take 20 years to become cost neutral, even if 50% of heating energy is saved.

Hence the **Target Cost** for the Retrofit Approach was set at **£10,000**. The resultant cost from the demonstration properties, combined with evaluation of potential savings in time and material cost, show a future **Expected Cost** of between **£15,000** RetroFix™ and **£30,000** RetroPlus™ for the 4 properties including VAT. VAT needs to be considered as it will affect the viability of the Retrofit Approach. VAT reduction should be considered by the government for retrofit work. These costs exclude contingency for unexpected work due to hidden conditions and are after process improvement and material cost optimisation.

[5] ETI's Optimising Thermal Efficiency of Existing Homes project 2010-2012

Without an identified pathway to achieve the target cost; the approach should now be to:

- Identify market sectors or conditions under which the expected cost is viable.
- Demonstrate that the expected cost can be achieved or improved upon.
- Use insight from further demonstration, at increased scale and repetition, to identify further cost and process improvement potential.

This is explored further in the following sections.

7.1.2. Cost Options

With a variety of property types and options; the previous analysis set out in Report 1 does not contrast the core specification options for a single property. The range of cost options is presented in a single table here to demonstrate the implications of four solution choices for one of the properties (RD9).

RetroFix™ with render
Full EWI including below DPC, ventilation with heat recovery, loft top-up insulation, basic draught-proofing.

RetroFix™ with brick slips
As above but with hand applied clay brick slips (extra challenge to achieve 10 day programme)

RetroPlus™ with render
As render above plus triple glazed windows, floor insulation and reduced air permeability.

RetroPlus™ with brick slips
Combination of RetroPlus™ and clay brick slips

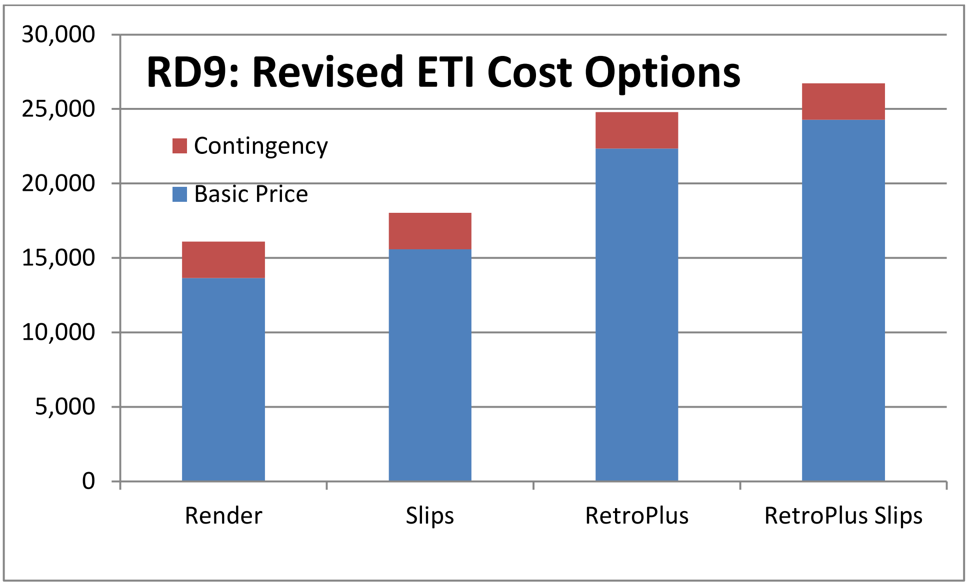

Figure 5: RD9: Revised ETI Cost Options

These future expected costs for the Retrofit Approach show that our current best estimates of market pricing are well above the £10,000 target cost for RetroFix™ and the higher average £18,000 target for RetroPlus™.

For the model to be viable at these costs the retrofit proposition needs to demonstrate additional value to the householder or it will need incentives, perhaps in the form of subsidy, to generate demand.

7.1.3. Trigger Points

One mechanism to overcome the cost hurdle is to encourage property owners to add retrofit to a necessary replacement or repair and demonstrate that the additional cost is considerably less than if the measures were tackled independently. Examples of trigger points and their costs for a property similar to RD9 are given below:

Re-rendering: typical cost £3,000 per property @ £30/m^2
This can be fully offset against RetroFix™ costs – meaning that a £15,000 retrofit has an additional cost of £12,000 above the necessary repair.

Fascias, soffits and guttering: typical cost £2,000 per property.
50% offset against RetroFix™ costs with the guttering / soffit material additional to the retrofit cost.

Window replacement typical cost £6,000 – 30% of this amount is offset against the RetroFix™ costs and 100% offset against RetroPlus™

Even with the offset of costs at trigger points, the capital outlay is higher than the £10,000 watershed. As a result the delivery organisation will need to be adept with marketing and financing models to attract customers to invest.

7.2. Time Analysis

The challenging time targets set for the Retrofit Approach are crucial for the commercial proposition in two aspects:

- Time on site is the most significant driver of cost both for poly-competent team labour and for welfare facilities, management overhead and, to a lesser extent, scaffolding (45% - 55% of cost in total).
- From a householder perspective, programme is a crucial aspect of the proposition, and feedback from the properties was consistent and clear that a reduced programme was more important than reduced disruption on site.

From the project team's perspective, it was notable that householders' morale and support for the works dropped significantly with programme delay. We cannot be sure how much of this is as a result of failing to meet their expectations for completion, or whether after the third week the intrusion of scaffolding and the team on site caused 'retrofit fatigue' amongst residents. Our hypothesis is that both are significant but that the absolute timing is more important.

There are three key aspects which need to be addressed to enable the repeatable achievement of the challenging 10-day typical RetroFix™, or 15-day RetroPlus™, programmes.

- Process
- Productivity
- Delay

Each is discussed below.

7.2.1. Process

To achieve reliable programme timing each element of the retrofit process needs to strive to be robust and repeatable in both time and quality. A traditional approach to refurbishment is along the lines of '*We've got the idea, but every project is different. Let's get started and we'll work it out as we go.*' With experience this way of refining the process will yield improvement, but the learning will not be robust or scalable. With a more analytical review of site processes the project team observers have logged tasks which have taken disproportionate time or resulted in error and rework. These have been used to develop the opportunities for improvement in product and process.

Process improvement has been explored using the following **'ECCR'** hierarchy, which is described using examples from the project:

Eliminate tasks and/or material, (e.g. eliminate the need for screw fixings for IWI with sufficiently improved adhesive)

Combine components *or processes* to reduce task time, (e.g. a panelised system which applies insulation, render and surface finish in one item);

Combine operations to complete multiple activities simultaneously and thus save time or labour, (e.g. larger areas of (pre-cut) insulation to reduce cutting time and the number of fixings);

Reduce time or cost of any residual operation or component, (e.g. speed up re-fixing of satellite dishes with drilling templates and brackets pre-prepared with sealing tape).

Once the need for each task has been challenged, process improvement is enabled in three ways:

Process design – analysis of the task which needs to be achieved and organisation to ensure standardisation of: sequence, timing, material presentation, tools, equipment and methods.

Product design – innovations / adaptations materials and more particularly components to make them easier to install (e.g. inter-linking basetrack as an improvement to fiddly plastic clips).

Tooling and fixture design – creation of jigs, templates and other aides to reduce the need for operator skill, measurement and judgement (e.g. brick slip setting out grids and spacers).

7.2.2. Productivity

Site observation assessed productivity of the installation team on site at the four houses and there were wide variations by task, team member and stage of the programme. Productivity, assessed as the percentage of time spent effectively completing tasks necessary to deliver the retrofit, varied from 70% over the period of a day to less than 10%. With multiple team members, over multiple week programmes the data collection has not been sufficient to give a precise assessment of productivity losses, but the following sub-sections give an indication and ranking of the losses:

Process
The Retrofit Approach aims for significantly reduced levels of air permeability and thermal bridging than current delivery. As a result the poly-competent team was being asked to work to more exacting tolerances than they were used to, or expecting. Using the same processes and techniques as previously sufficient, but just *'trying harder'* will not create capability; hence the need for process improvement as described above and, in some instances, the need for complete process redesign. Developing standard processes, aligned to the final specification is the most significant opportunity for productivity improvement. Once 'standard work' is in place it becomes the benchmark against which individuals and teams can assess their performance and crucially a measure against which process improvement can be tested.

Planning
For RD9, and initially on RD1, the lack of planning for each day's task to ensure all materials, consumables tools and skills were available to complete the task was the dominant cause of reduced productivity. The effect was multiple 'blue-light' trips to local builders' merchants to collect items which held up progress. This was, in part, a result of an inexperienced team leader, but compounded by a lack of planning tools and an agreed approach. With the simple, 10 minute 'Sunrise and Sunset' planning sessions requirements and shortages were identified in time to prevent delay of tasks.

Skills
The skills of individuals have a significant bearing on productivity and this was particularly noticeable in the application of brick slips. The experienced specialist EWI team on RD27 installed 50% faster than the developing poly-competent team on RD5. Craft skills like brick-laying and rendering of top-coat finish are highly dependent on experience developed over time. To enable retrofit capability to scale; the

challenge is to develop processes and products which are less craft ability dependent: This will enable a shorter learning curve for operators and more rapid growth in the number of productive teams.

Payment models and Behaviour
Payment of installation teams on the basis of square metres of EWI installed is common in retrofit. This drives a focus on speed which is valuable, but also risks installers cutting corners on quality, or ignoring co-ordination activities which would benefit the retrofit as a whole. At the other extreme, where teams are paid on a 'time and materials' basis, there is a temptation to reduce the focus on programme and allow task duration to stretch considerably. Both aspects were experienced at times on the project; even with the most motivated team (to a limited extent).

Achieving a balance which encourages and recognises both quality and speed of delivery is important as is incentivising those who develop innovations which can reduce programme time or errors and defects. Experience in other sectors shows this has more to do with leadership, management style and recognition of performance than direct financial incentive.

Attitude
In the initial poly-competent team there was a blend of EWI specialists and multi-trade (electrical / plumbing / building) skilled individuals. The EWI group were reluctant to explore alternative ways of working; believing they already knew the optimum approach. This made it challenging to coach improvement and to an extent was a cause of the wall failure on RD5, where a lack of care using hammer drills to secure EWI fixings caused the external skin of the cavity wall to be locally pushed into the cavity.

7.2.3. Delay

Delays experienced on the demonstration properties arose from three aspects:

Co-ordination
In any process the number of interactions between organisations and suppliers has a direct impact on the likelihood of delay. Unless all parties are aligned to the same priorities; delays are to be expected. In construction, delay resulting from co-ordination of trades is a major issue and the concept of the poly-competent team successfully addressed this (particularly on RD1 & RD5), despite the warnings from many experienced construction professionals who did not think that an electrician would work on insulation tasks.

Where lack of co-ordination did cause delay was with procurement and liaison with external organisations. Scaffolding companies were notoriously unreliable in meeting dates they had committed to and caused further delay by erecting systems without meeting the EWI installer requirements. Material suppliers did not always achieve required dates for delivery and this was a result of both failure to order early enough, but also poor co-ordination within the suppliers. With an established supply chain at scale these issues could be easily rectified, but only if attention is paid to designing a robust co-ordination process. The alternative option of bringing access provision within the Poly-competent team and material stock 'in-house' as part of the Retrofit model is an alternative which may reduce delay if closer integration proves challenging. Procurement of small items (material, consumables and tools) caused significant delay on RD9 and RD1. However, with the adoption of Sunrise and Sunset team planning sessions these delays were almost eliminated for RD5 and RD27.

Decisions Required
Although less obvious than a shortage of material or plant; delays resulting from a need for technical or design decisions (e.g. "This item won't fit. What do you want me to do?") are frustrating to the installation team and lead to a noticeable drop in productivity, even if there are other tasks that can be tackled whilst they are waiting for an answer. Commercial decision delay was significant on the social rent tenure properties linked to (i) building condition (e.g. "This item is rotten and needs replacement. Do I have permission to replace it?") or (ii) tenant request (e.g. "The tenant is asking for a new outside tap which has a cost implication"). Both of these delays can be reduced or eliminated with carefully designed operating procedures. Condition issues should be assessed for potential failure modes by the team leader on a daily basis and plans prepared for the eventuality of finding a condition problem.

Weather
Wet and cold conditions caused significant delays on the project particularly on RD1 (February) and RD27 (November). Rendered solutions are particularly sensitive to rain – with splashes ruining the aesthetic and requiring rework. For render and adhesive (including for brick slips) temperature below 5°C or rapidly falling temperatures mean work must stop. Wrapping the building with mono-flex sheeting and providing heating more than doubled the cost of the scaffold on RD9 and is unlikely to be viable. This sets a challenge for the supply chain to develop all weather solutions – ideally creating a panelised dry-fix solution which also improves site productivity.

7.2.4. Addressing inefficiency to achieve target programme

Tackling the challenges of process, productivity and delay is crucial to the achievement of a repeatable 10 day retrofit programme. The ambition at the outset of the demonstration project was to show incremental improvement during each iteration and so set a trajectory that gives confidence in the ability to achieve the 10 day target. However, the diversity of the properties, the technical challenges encountered and the learning curve for both the poly-competent team and the project team confirmed that the scale of the task had been underestimated.

With the potential for improvement identified and described above the project team's assessment is that a 10 day programme could be routinely achieved, for typical 3 bedroom properties, if productivity levels are improved to 50% or more. Render and adhesive curing / drying times are crucial to the programme and need to be reduced and/or removed from the critical path (e.g. pre-finished, dry-fix panels) if the 10 day programme is to be improved upon and reliably achievable for larger detached properties.

Recommendations for improvement are covered in Sections 4.4. The Retrofit Approach – gaps and issues and 4.5. Barriers.

7.3. Energy Performance Guarantee

A performance guarantee would need to be provided by the retrofit installation company or a connected third party. There is at least one existing installer in the UK that offers such a guarantee on residential retrofit work and it liaises with residents after the work is complete to ensure that heat energy use is minimised while comfortable internal conditions are maintained.

Some housing landlords have asked residents to contribute towards the retrofit costs by making small monthly payments which are covered by part of the energy bill savings. The resident benefits from improved internal conditions and utility bill savings.

The in use heat balance test findings from this project demonstrate at least a 25% reduction in heat energy use for all homes in this project post retrofit. Although we would recommend further verification of the test and the results is made, the initial tests suggest that a performance guarantee could be offered in relation to 25% heat energy use reduction.

This typically relates to an approximate current £250.00 saving per year in energy costs.

8. Roadmap to develop industrial capability for Retrofit Approach

This section summarises the activities required to develop capacity and capability to deliver the Retrofit Approach at scale. Barriers and obstacles to successful deployment are also considered as well as opportunities.

The sub-sections focus on:

- Materials and Products
- Installation
- Technical
- Commercial

Recommended actions arising from each are highlighted at the end of each sub-section and summarised in a top-level roadmap of activity with outline costs in section 8.5.

8.1. Material and Product Capacity

Capacity for the core insulation and building products used in the Retrofit Approach is still underutilised as construction, and the RMI market in particular, gradually recover towards activity levels which peaked in 2009. This means retrofit will not be constrained by bulk material capacity in the short and medium term. However, the consequence of the market downturn is that there has been, and may continue to be, a lack of significant investment in energy efficient product innovation at scale. For retrofit there is a need for very high performance, but affordable, insulation and the manufacturing and supply of niche products (aerogels and vacuum insulation) has not been industrialised to achieve a step-change in cost and volume.

Similarly ancillary products, such as heat recovery fans, have only made modest inroads into the market as there is limited understanding of their application and performance in use. Without demand growth there is little competitive pressure on pricing and performance to make the products more cost-effective. This may be a result of a lack of a clear and aggregated voice from retrofit designers and installers setting out their requirements / specifications for retrofit solutions.

Two activities could stimulate the innovation required:
(Italics show how the activity fits in to the draft Roadmap in Section 8.5)

- Aligning industry experts or innovation bodies to set a range of technical and commercial challenges to product developers both large and small.
  For example: The retrofit market needs a rigid insulation for window reveals with finish that can be painted or rendered and a λ value of 5mW/m.K, for less than £10/m^2.
  (Roadmap: 2 – Stakeholder Engagement, 10 – Supplier Development)
- Engaging with consumer products brands to raise the profile and desirability of retrofit products.
  For example: A Dyson Heat Recovery fan may enable a step change in profile and demand.
  (Roadmap: 2 – Stakeholder Engagement, 10 – Supplier Development)

For product suppliers the revised material content of RetroFix™ is £2,500-£4,000 and approximately £10k for RetroPlus™. Assuming each team installs in 20 homes per year with 80% RetroFix™ at mid-point costs material demand will be £88k per team per year. At the scale of EWI installation achieved during CERT in 2012 (22,000 homes) demand equates to £100million per year. This would still be a very small proportion of the £14bn RMI market. Only once retrofit achieves growth over 100,000, towards the one million homes a year needed to achieve the UK's Carbon Reduction Commitments, will demand form a significant part of the market.

8.2. Installation Capability and Capacity

8.2.1. Installation Capability

The poly-competent team is at the core of the Retrofit Approach and the model is at odds with the current construction industry paradigm of trade skills. Technical colleges and training schools are still aligning apprenticeships with trade skills and, although multi-skills courses are being developed (City & Guilds and others), they do not cover the full range of skills required for the retrofit specialist or team leader.

The multi-trade team that worked well on RD1 and RD5 was developed as a family business; recognising the value of adding electrical and gas fitting skills to a general building business.

The demonstration projects have revealed that there are some short-comings in installers technical skills but that one of the most significant short-comings is the capability to plan ahead to achieve programme work collaboratively.

The following activities would be valuable to develop installation capability:

- Building a detailed skills matrix for retrofit works to develop an in-depth assessment of capability needed and at which stages of different retrofit projects. This may demonstrate that it is possible to reduce the capability requirements of retrofit teams for some property and intervention types. This will have the benefit of providing a development pathway for teams, as well as individuals, and potentially reducing the team cost for some projects.
  (Roadmap: 2 – Stakeholder Engagement, 1 – Technical R&D)
- Developing scopes of work and competences with Gas and Electrical accreditation bodies[6] to build a structure of retrofit tasks which can be tackled by retrofit team members under-training. This will then clarify the level of competence needed in the team leader or how gas and electrical tasks can be checked and signed off with accredited experts from outside the team.
  (Roadmap: 11 – Stakeholder Development, 13 – Skills Development)

Further work is needed on the specialist skill (gas /electrical) requirements to balance the value of the poly-competent team availability with the proportion of tasks needing these skills. A hybrid model, with members of the team trained but not accredited for specialist tasks, supported by fully qualified technicians, with responsibility across a number of teams, has a number of benefits:

- Reduces the retrofit requirement for electrical and gas skills which are often in short supply at some points in the economic cycle and may attract premium pay rates.
  Gives a career development pathway for retrofit operatives from labourer, to building skills, to electrical or gas skills to full qualification.
- Gives organisations with multiple teams an opportunity to create specialists teams which tackle more complex projects with additional add-on offerings beyond retrofit.

8.2.2. Installation Capacity

Installation capacity will need to follow demand and currently the project team envisage the most predictable requirement for retrofit work coming from the social housing sector. Tailoring capacity to this market will give an opportunity to develop and refine the RetroFix™ and RetroPlus™ offerings and build capability in a sector which is experienced in routine maintenance, rather than the more critical consumer market. Many Registered Providers are currently dissatisfied by the cost and service provided by commercial facilities management companies; this could be a trigger to develop new capacity if there are options to collaborate with other organisations to reduce the risk of investment.

The following activities would be valuable to develop installation capacity:

- Explore with registered providers the potential of developing an in house capability for minor works and retrofit. *(Roadmap:2 – Stakeholder Engagement, 11 – Stakeholder Development)*

[6] Gas Safe, NICEIC / NAPIT

- Partnering with supply chain organisations and designers to develop an end to retrofit model.
  (Roadmap: 2 – Stakeholder Engagement, 10 – Supplier Development)
- Link retrofit works with registered provider void properties upgrade: refurbishing properties as tenants move out is a vital activity for landlords and, without residents in situ, a low-risk opportunity to refine the retrofit model and build capability and capacity.
  (Roadmap: 2 – Stakeholder Engagement, 9 – Market Development)

The institutional investors in the private rented sector could also be a powerful driver of change. Like the social landlords they are unconvinced by the capability of existing FM organisations to maintain their assets cost-effectively. Such organisations have demonstrated their willingness to invest in new business models for new build construction[7] and the same may be true for retrofit.

8.3. Technical Capacity

The key areas of technical capability required are:

- Property Survey
- Retrofit design and detailing

The survey process is a significant challenge: Without a good survey there is increased risk in the installation process, but a fully detailed technical survey crosses many disciplines and for certainty of construction and condition the survey cost may exceed that of the retrofit. Further work is needed to develop a fit for purpose model and a specialist retrofit survey capability.

There are a limited number of specialist organisations who understand the building physics of retrofit and can combine this with architectural capability. Even fewer can link this with the principles of installation process design and buildability whilst taking in to account supply chain and logistics.

This reinforces the need for cross-industry collaboration to develop common design and technical standards; rather than individual practices developing proprietary standards and competing in a way which confuses a market which struggles to understand the value of retrofit.

There will not be universal standards covering every property and so there will be a need to develop a central repository for standard details which are the best practice solutions by house type. This library will be a key asset on which to build a robust Retrofit roll-out. If the library can be centrally funded, with limited cost to access: it will encourage industry collaboration and raise the standard and reputation of retrofit.

The following activities are proposed for developing technical capacity:

- Linking retrofit design specialists with the Royal Institute of Chartered Surveyors to develop a template for property assessment with a retrofit focus.
  (Roadmap: 2 – Stakeholder Engagement, 11 – Stakeholder Development)
- A collaboration between retrofit experts, to develop open-source standards and design guides to raise awareness of installers, manufacturers and landlords and stimulate the standardisation and simplification of retrofit design, products and processes.
  (Roadmap:3 – Technical R&D, developed further in *13 – Skills Development)*
- Development of systematic campaigns by housing archetype to build a 'design library' of property specific details to enable the industrialisation of the Retrofit process.
  (Roadmap:9 – Market Development)

[7] L&G Homes: www.legalandgeneral.com/homes/

8.4. Route to Commercialisation

From the research, it is clear that there is currently only limited latent demand for retrofit and that such demand is at a very challenging price-point compared even to the future expected cost of the RetroFix^{TM} package. Once a robust market offering is presented and visible the pricing may become less critical provided RetroFix^{TM} can demonstrate both value for money and genuine householder appeal.

Demand is a key driver of both capacity and innovation and there will almost certainly be a need for elements of stimulus to shift the market. The risks of unintended consequences of subsidy have been clearly demonstrated by both Feed-In Tariffs and the Green Deal Home Improvement Fund. Significant levels of funding injected and then withdrawn have:

- Stimulated rapid growth, which is unlikely to be universally high quality or even capable,
- Driven inappropriate commercial behaviour amongst some less scrupulous providers who exploit or circumvent the intention of the subsidy.
- Lead to the collapse of both capable and well run businesses and organisation as well as the opportunists and cowboy fringe.

This research has confirmed retrofit is not a quick fix for energy efficiency. In particular the challenges experienced with the Green Deal will mean commercial organisations are unlikely to be enthusiastic advocates of aligning with the next initiative; fearing that the approach may not tackle the end to end process and / or be abruptly withdrawn as a political policy change.

The project team's charter for the development of a future retrofit market would include:

- Well planned and lightly subsidised, cross-industry solution development;
  (Roadmap: 2 – Stakeholder Engagement)
- Controlled testing of supply chain and technical solutions at scale
  (Roadmap: 4 / 5 / 6 – Pilot Project Design / Skills / Delivery)
- Launch of a market tested incentive scheme which stimulates but avoids 'over-cooking' the market
  (Roadmap: 11 – Stakeholder Development, 14 – Programme Roll-out)
- A clearly signposted pathway to the reduction and elimination of incentives
  (Roadmap: 11 – Stakeholder Development)

An outline proposal for the timing and initial investment required is proposed in the following section.

8.5. Roadmap

The project team's conclusions are that the key elements of commercialisation will require central government stimulus to develop retrofit in the following stages:

1. **Programme commissioning and technical design** **15 months, ≈£200k**
   Including stakeholder alignment (BEIS, DCLG, CITB, RIBA, RICS, NIC/EIC, Gas Safe, Build UK)
   Cross industry expertise to develop solution agnostic technical standards.
   Integration of survey and design processes to improve outcomes.
   Focusing on energy performance and enabling tools e.g. survey App., ventilation products.
   Development of a national design library of retrofit best practice – with plans to maintain it.

2. **Pilot proof of concept at mid-scale** **12months, ≈£430k**
   A phased programme of retrofit in a local area: With others funding the physical works.
   Two or three teams refining a standard RetroFix^{TM} approach on a common local archetype.
   Deliver up to 50 properties over a 12 month period: Capture insight and standardise processes.
   Potentially as part of the Energy Systems Catapult SSH Programme
   A programme to refine technical solutions and delivery standard work **6 months, ≈£100k**

3. **Market Engagement & Value Proposition design** **9 months ≈£90k**
   Engage with key market organisations to establish barriers to investment.
   (Local Authorities, Registered Providers, Private Rented Sector)

(Material suppliers, product manufacturers and logistics companies)
(Training organisations, professional bodies, technical accreditation, energy utility companies)
Stimulus in target sectors; 2 years (£ TBC)
Clearly designed to drive innovation and desired behaviours in the market and supply chains.
Stimulus should be designed only to give support whilst the market pull for retrofit is unproven, or where there is a need for scale to demonstrate the potential for reduced cost.

4. **Development of skills and capability 2 years (£ TBC)**
   Codification of design and process details needed for retrofit and associated works
   Detailed capability development programmes with trade and skills bodies (CITB, ICS, Gas Safe, Build UK, NIC-EIC)
   Links with education (e.g. City & Guilds)

5. **Industrialisation of product and retrofit process Likely to take 5 years**

The stages above are represented graphically as a five year programme on the following page.

These timings are estimates and do not take into account the additional time to formally commission projects or enact any necessary policy and regulation change.

It is important to note that part shaded activity shown on the roadmap is part of the recommended action plan, but is not costed for two reasons:

- At this stage the scale of activity is unclear and requirements will emerge from the initial phases.
- The investing organisations are likely to be very different from the costed activity, which is primarily research. e.g.

  - Market stimulus – through BEIS or DCLG but highly dependent on the political environment.
  - Skills development – through CITB and professional / accreditation bodies.
  - Industrialisation – to be funded by the supply chain once the market requirements are clear.

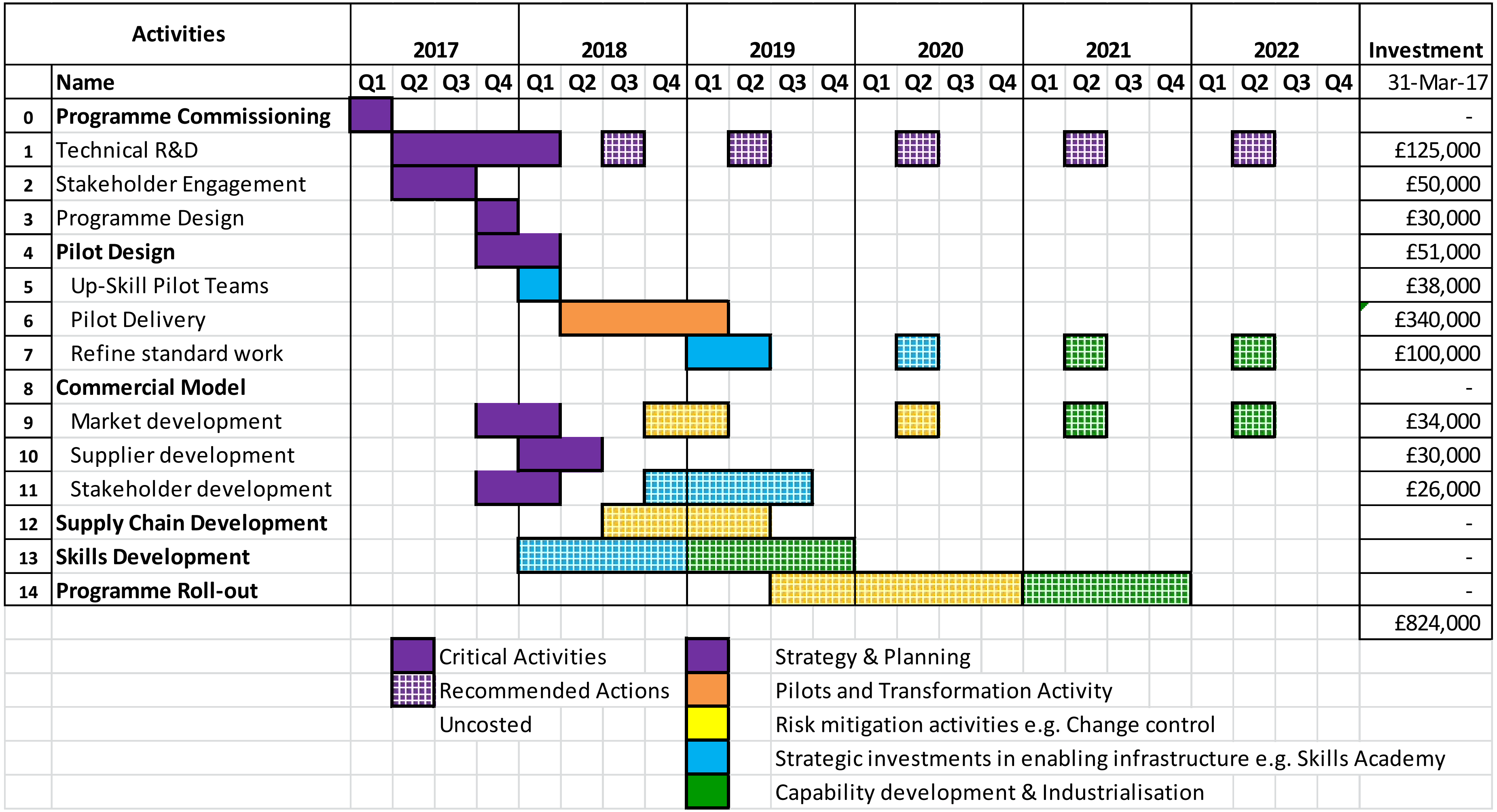

Figure 6: Five year Roadmap to Develop Industry Capability

9. Final Conclusions

In conclusion, it has been clear from this project that the Retrofit Approach could be a successful delivery model subject to the following:

- Production of a standard set of installation details in a cloud based library and linked decision tool;
- Development of more efficient and advanced existing condition survey methods;
- Product and manufacturing process development by suppliers to improve material and system technical performance and reduce installation times;
- Development of on time supply chain logistics and material recycling processes
- Further review of the industry skill base required for the Retrofit Approach and development of a training programme to create better skilled teams with a better understanding of the required installation quality
- The introduction of frequent and robust quality inspections

There are other requirements which are needed to create a retrofit market in which the Retrofit Approach can be successful and these include the development of funding and finance mechanisms, enabling real estate agents to consider the value of retrofit measures and a streamlined planning application process for EWI, however these do not directly influence or have a major impact on the Retrofit Approach hypotheses which this project set out to establish could be achieved.