OPTIMISING THERMAL EFFICIENCY

OF EXISTING HOUSING

Summary Report
Energy Zone Consortium
September 2012

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Premise

The backdrop for this project has been the UK's 2050 Climate Change Commitments and so the requirement has been to develop pragmatic solutions which can make a significant contribution to meeting the mandatory 80% reduction in UK CO_2 emissions.

There is a great deal of valuable work on energy efficiency being carried out both on national policy and at the individual property level. This project has endeavoured to consider the end to end value chain for domestic dwellings whilst focusing primarily on thermal efficiency (heat).
The objective has been to carry out rigorous, but desk based, research to conceive a future state where there are mechanisms, appealing to householders, which greatly reduce the energy demand of existing domestic properties (more than 50%).

With 26 million UK properties the prime considerations have been the challenges of engaging with households and the practicality of delivering at scale within the 37 year timeframe.

Team

The project team was assembled to bring together expertise from across the energy landscape: Energy modelling, at both building and national slock levels, from University College London and the BRE; Social Housing and householder engagement through Peabody Trust; Environmental architectural design expertise of PRP; Energy supply and technology from EDF Energy; Retrofit supply chain experience through Wates and innovation from Total Flow, with material expertise of BASF. Policy, health and safety aspects were also led by BRE.

Approach

To meet the two year project timeframe the team refined the computer models in parallel with consumer research and development of new solutions and delivery models. The close collaboration to make this work required regular workshops; both within the team to review interim results and with external organisations to challenge and peer review findings.

Findings

The project has provided valuable insight by enhancing existing energy models, completing new consumer research and developing design, supply chain and policy solutions which challenge existing paradigms.

In this report the findings are presented as responses to a series of questions:

What does the householder want?
Consumers need increased confidence in both the need for retrofit and in suppliers' ability to deliver with minimal disruption, whilst meeting an investment ceiling of £10,000. Within the UK population the project has identified age and income profiles which define groups that are more likely to take up retrofit ahead of the curve.

Figure 1. Resident consultation.

What are the ideal solutions?
There are both consumer and technical drivers to tackle retrofit by doing it once and doing it properly. RetroFix is proposed as a minimum solution; which takes walls and loft insulation beyond current cavity wall insulation performance and upgrades to the most efficient heat sources (boilers). At the recommended RetroPlus level floors, doors, windows are tackled beyond the RetroFix measures.

Where should retrofit be focused?
The research has identified house types and geographical locations which link with early adopting householder groups. Modelling shows that older properties tend to have significantly higher current energy consumption and hence potential saving, albeit with a wide spread of energy use across each population.

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Executive Summary

What is the impact of proposed solutions?
If adopted across all property and household types Retrofix could deliver a 33% energy saving and the recommended RetroPlus a 50% saving. These reductions are moderated to take into account the impact of comfort taking and researched underperformance versus predicted values.

How can retrofit be delivered effectively?
In the absence of whole house Retrofit providers; existing supply models need to adapt, or be replaced by, offerings which minimise cost and disruption. The proposal is for four-man, poly-competent installation teams with the capability to deliver all activity in less than two weeks. Material and process innovation is crucial to enable this.

Figure 2. Retrofit work on site.

How does policy need to change?
There is limited latent demand for home energy improvement, but from the consumer research householders are willing to engage when prompted. A sliding scale of Stamp Duty will increase demand, while a mandatory minimum Energy Performance Certificate will act as lever for change.

What is the value of retrofit?
With current UK Government energy price predictions payback periods for householders remain over 10 years at current Mortgage Rates even with the projected 30% reduction in the cost of measures. To help the market grow; providers will need to rise to the challenge of making Retrofit attractive in aesthetic and other ways.

Challenges

There are technical challenges to overcome to make RetroFix and RetroPlus packages both attractive and cost effective. However, the most crucial challenge is to stimulate consumer interest in investing in energy efficiency. Payback alone will not be sufficient and long-term Government subsidy is not viable.

The savings presented are outputs from a refined and enhanced building physics and stock model. Although user behaviour and in-use factors have been included practical validation is needed to confirm the level of energy saving achieved at scale.

Market and press reaction to the initial rollout is crucial to future success: Early failures in performance, service or cost will be very difficult to recover from.

If suppliers and installers are to put effort into developing new offerings they need to have confidence that the regulatory landscape is favourable to Retrofit and policy will remain consistent for investors to make a return.

Future Work

To build on the findings of this project the team recommend that the proposals are tested with both practical and further academic research.

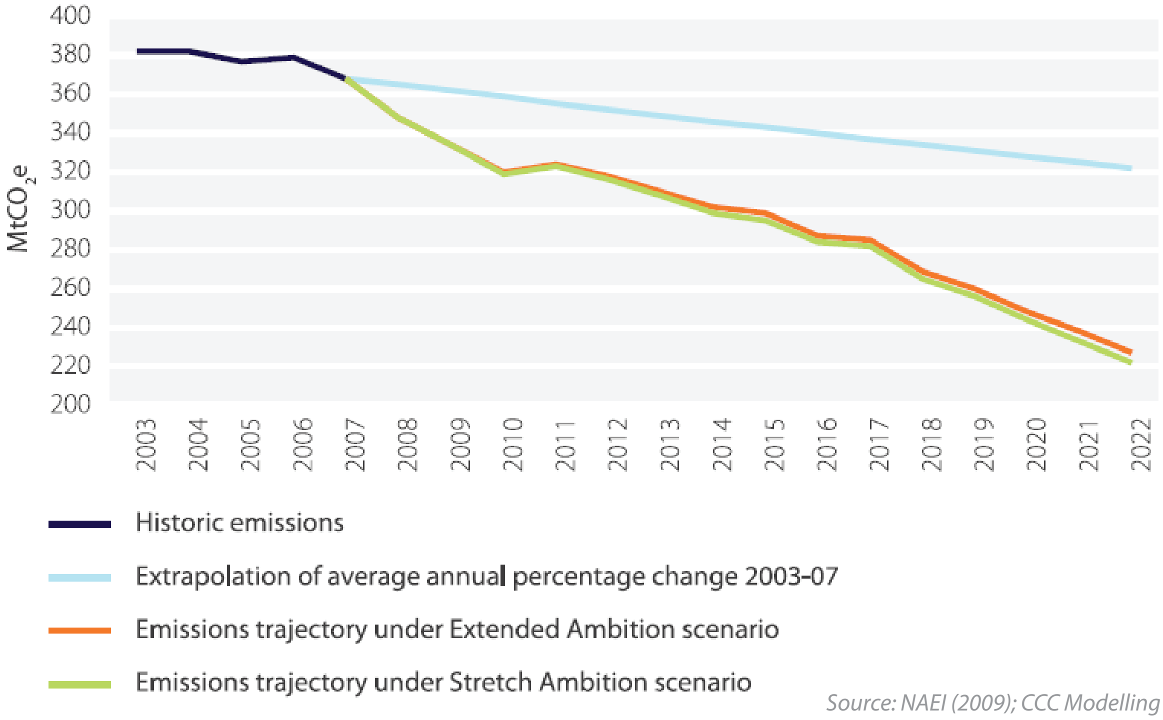
Practically the design and supply solutions need to be tested at the 10 and 100 home scale to prove the approaches can meet consumer requirements for cost and disruption; whilst also gathering real energy consumption data to validate and refine the predictive models.

Further academic research would be highly valuable to understand the impact that Retrofit has on property values; the level of change will have a significant influence on Retrofit volume.

02
Background

The 2011 UK Carbon Plan states that "by 2050, all buildings will need to have an emissions footprint close to zero". In addition, the UK is legally committed to an 80% greenhouse gas emissions reduction target for 2050, with five year carbon budgets in the interim. With estimates predicting significant increases in energy use as a result of population growth and increased demand, these ambitious goals can only be achieved through significant improvements in the energy efficiency of the building stock and the decarbonisation of the UK's energy supply. Improvements to the thermal performance of the UK's buildings are pertinent not only to meet future carbon emission targets, but also improve health and comfort, reduce fuel poverty, improve energy security and help smooth peaks of heating demand. This project concentrates on the tools, processes and technologies required to improve the fabric of our existing housing stock.

Figure 3. Recent buildings and industry CO_2 emissions and reductions under Committee on Climate Change emissions reduction scenarios



Source: NAEI (2009); CCC Modelling

This report summarises the results from a two year, Energy Technologies Institute (ETI) funded project, undertaken by a multi-disciplinary team to help plan for the energy efficient retrofit of the UK housing stock. In particular, the project endeavoured to understand the following questions:

- What do home owners want from an energy efficient retrofit?;
- Where should the initial focus for mass retrofit be, both geographically and within a property?;
- What are the best combinations of measures and what impact will these measures have not only on energy consumption, fuel prices and carbon emissions but also the unintended consequences on overheating and health?;
- How can we deliver the energy savings cost effectively and appeal to the householder?;
- What policies would best support the rollout of such a mass retrofit programme?

The original specification of the project was a paper- based research project with the results feeding into a future field trial of the energy efficient retrofit of homes. This field trial is now planned under the ETI's Smart Systems and Heat project, where up to 10,000 properties will be retrofitted and smart technologies and systems trialled beginning in 2015. The project has been undertaken during a rapidly evolving period of policy and field trials in the area of low energy retrofit.

This has included the development of the Green Deal, the TSB Retrofit for the Future project, IGT's Low Carbon Construction Action Plan and creation of the Green Construction Board, which advised the establishment of a Retrofit Hub. Where possible this project has engaged with these other initiatives, building on the lessons learnt by others and feeding preliminary results into DECC and other ETI stakeholder organisations.

03

Methodology

Methods and outputs

The consortium has undertaken a very diverse range of work over the last two years which has resulted in the production of 36 reports (see Appendix B for the full list) and the development of two energy models; a building and a stock model.

The methods employed have included the following, many of which have been used extensively during the project:

- Literature reviews
- Collaborative workshops with Government and industry stakeholders
- Interviews and focus groups as part of consumer engagement exercises
- Profiling consumer and dwelling typologies
- Developing a series of retrofit packages and testing for their technical performance with the ETI Single Dwelling Model
- Developing improved supply chain models and installation programmes for the retrofit packages
- Developing and testing an innovative dwelling and stock model
- Modelling future scenarios and simulating unintended consequences including overheating, comfort taking and mould growth
- Simulating the summer indoor thermal performance of 1,440 dwelling variants using the dynamic building simulation software Energy Plus to assess indoor overheating risk post-retrofit
- Evaluating the potential impact of wall insulation on the extent of two and three dimensional thermal bridges using the steady state heat transfer software TRISCO

Key innovations have occurred because it was undertaken by a highly collaborative team of practitioners and academics with a very wide range of disciplinary skills including:

- Architecture and surveying
- Engineering
- Building science
- Manufacturing
- Process engineering
- Construction
- Health & safety

Figures 4, 5 and 6. Stakeholder engagement workshop.

04

What does the householder want?

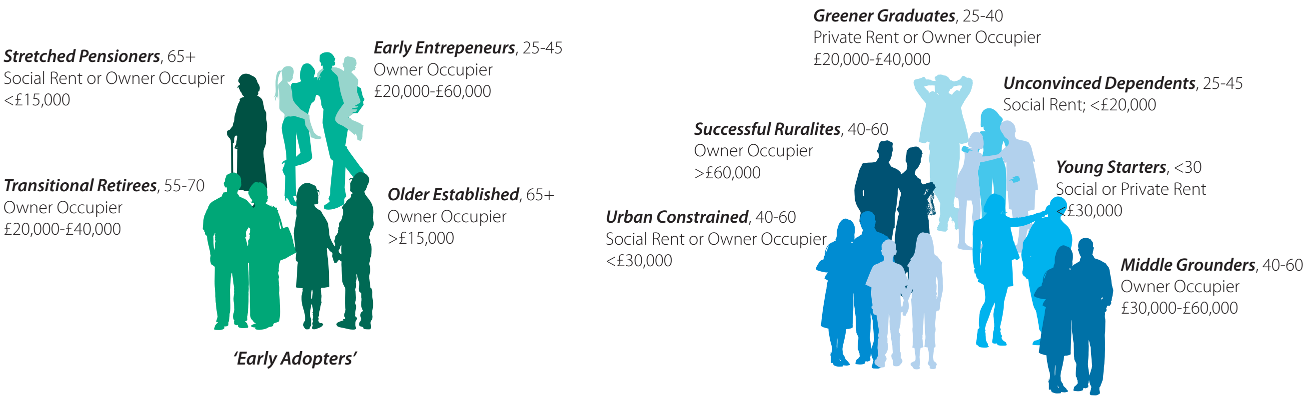


Figure 7. Customer segments with age band, tenure and income.

In order to better understand the public's awareness of retrofit and develop retrofit solutions tailored to consumer values, a number of customer segmentation groups were identified and selected for further analysis. These groups, along with their age bands, tenures and income levels, are outlined in the image above.

Customer awareness and acceptance

Awareness of retrofit was typically poor across all customer types/segments. Whilst most customers were aware of measures such as loft insulation, cavity wall insulation and energy generation technologies like solar photovoltaic, almost all research participants were unaware of solid wall insulation.

One of the key findings from the work conducted on Customer Engagement is that across all segments, money is still the primary focus of customers in relation to retrofit (from upfront cost to potential savings achieved) followed closely by personal comfort (mainly temperature but also other factors such as air quality, noise and security). A limit of £10,000 emerged from discussions across all segments as a threshold beyond which works would be deemed as too expensive.

The findings of the work clearly indicate that no segment is motivated enough by CO_2 emissions or "green" concerns to carry out large-scale retrofit works to their homes. This disassociated responsibility also transfers to customers' attitudes towards retrofit measures. With a significant proportion of customers having installed (or been aware of) insulation measures that have been fully or partially funded (through the Carbon Emissions Reduction Target and other funding streams), there is an expectation and precedent that energy-saving measures should be provided and funded by "Government" or "energy companies" with customers failing to see the value of investing themselves.

Do it once, do it properly

•A common finding through the focus group and interview research was that many customers believed they had already completed retrofit works to their home to a suitable standard. When questioned on this, it emerged that this typically involved having loft insulation installed (in many cases, less than the recommended 300mm depth), double glazing and a recent installation of an efficient gas boiler. Overcoming this perception that works are not needed is seen as critical to the roll-out of retrofit

Finally, this observation adds validity to the concept of delivering whole-house "one-hit" solutions, avoiding the need to return to properties in future years to make further improvements. Customers are likely to be further confused or resistant if they are told in future that their retrofitted home needs to be brought up to higher standards of energy efficiency.

Many customers believe they have already retrofitted their homes due to small-scale energy efficiency improvements and have become accustomed to utility companies or Government supplying these works for free.

'Early adopter' segments are similar enough to design retrofit roll-out solutions that will appeal to the early adopting groups– focusing on local trades and improved advice.

'Early adopters' of retrofit

Part of the research focused on identifying potential 'early adopters', a small number of customer segments were more interested in retrofit and more receptive to the value propositions developed by the wider project. These groups were selected based on population size, openness and awareness of housing energy efficiency and potential access to funding.

The 'early adopters' were identified as those belonging to the following four customer segment groups: Older Established (Over 65, income £20-40k); Stretched Pensioners (Over 65, income less than £15k); Transitional Retiree (55 – 70, income £15-£40k); Early Entrepreneurs (25 – 45, income £20-60k).

For all four segments, the top reasons for why they would retrofit their home were "to reduce the energy bill of my home", "to make my home more energy-efficient" and "to make my home more comfortable". As such, these are the key messages to exploit when promoting retrofit to engage all four early adopter groups. Similarly, all these groups suggested that better information on television and radio and talking to an expert energy professional would help them make a decision on how to retrofit their home.

Figures 8 and 9. Customer focus groups.

Trust and disruption

Widespread mistrust of the building trades, from personal experience, experience of friends and family and from the media (particularly television programmes covering "rogue traders" and "cowboy builders") play a major part in shaping the desirability of conducting retrofit works to individuals homes.

Widespread mistrust of the trades remains a significant barrier to the uptake of retrofit as will any retrofit over £10,000.

Research has highlighted the importance of personal positive experiences with trades and personal recommendations from friends and family in helping customers select services to carry out retrofit works. Harnessing the power of personal networks is therefore essential in rolling out retrofit on a wider scale.

It was identified that local trades were the most likely to be trusted by customers – both those who had already had works carried out and those that were being asked to consider works. This supports the notion of widespread preference for personal recommendations from local friends and family rather than a large national provider with a broader workforce.

All segments were resistant to leaving the home in the hands of a contractor. The primary concern of customers is leaving the home with an unfamiliar group of individuals. As such it is important to further identify ways to help overcome the lack of trust in this area or to generate solutions that don't disrupt customers for more than two weeks, the maximum amount of time that was identified as tolerable.

A preference for personal recommendations from friends and family in choosing retrofit service providers highlights the need for customer engagement and marketing to harness the power of personal networks.

05
What are the ideal solutions?

The retrofit solutions developed in this project have been designed to achieve significant energy consumption and carbon emission reductions in relation to space heating and hot water while also considering cost, currently available technologies, aesthetic concerns and customer values. Different measures have been combined, using the expertise of the consortium and advice of stakeholders, to form whole house solutions.

The whole house packages include solutions that scored highly across the following five key aspects of a successful market offering or value proposition:

1. *Design and construction* (visual impact, aesthetic choices, ease of installation, waste minimisation, lead time)
2. *Supply chain* (offsite manufacture, materials availability, skilled installers, robust installation methods, scalability)
3. *Customer acceptance* (low disruption, ease of use, awareness, lifestyle impact, desirability)
4. *Policy* (funding mechanisms, quality assurance, health and safety, planning and regulation)
5. *Cost* (capital cost, cost of ancillary works, cost escalation risk, maintenance costs, funding availability)

While incremental piecemeal improvements do yield thermal efficiency improvements, their installation as a whole system would generate greater benefits in terms of cost effectiveness, enhanced performance, risk and damage mitigation, reduced waste and disruption minimisation.

"Do it once and do it properly" was the key to the generation of whole house packages.

This is not to say that individual measures should not happen at key trigger points; rather that mechanisms are needed to encourage whole house solutions at these points.

Two levels of intervention are proposed: RetroFix and RetroPlus.

RetroFix packages designed to tackle the most significant thermal losses in our existing housing stock. These packages typically include improvements to walls with external or internal insulation, loft, floor edges, improved airtightness and controls and heating system upgrades. The expected carbon emission saving is typically 33% (between 20-55%) for a whole house package.

RetroPlus packages include all of the solutions in the RetroFix packages plus further thermal improvements to floors, replacement doors and windows, more innovative heating systems and renewable technologies where appropriate. These packages are currently less attractive on a cost per kWh saved: new doors and windows have marginal payback, but remain attractive to consumers as part of the proposition. RetroPlus packages offer up to 18% more carbon savings compared to RetroFix, saving between 30-65%.

Under projected carbon factors and weather data for 2030, retrofitted properties demonstrated additional carbon savings of 1% to 7% for RetroFix and 5% to 12% for RetroPlus. Older properties, such as the pre-1919 detached, demonstrate considerably higher improvement in carbon reduction terms compared to a post-1980 detached property.

A third level of intervention, called RetroMax, was developed for reference to the two other packages. Retromax packages are based on a higher fabric performance (U-value) standards for the individual components, and are aligned with Passivhaus standards. To date the team has not identified viable mass-scale solutions to achieve the PassivHaus EnerPHhit retrofit standard.[1] Focused development of process and material innovation would be required in order to establish delivery mechanisms, a robust supply chain and evolved materials that will deliver this standard on a wide scale.

Two levels of intervention have been proposed: Retrofix and RetroPlus with the latter being the recommended option. A PassivHaus standard RetroMax as the ultimate target when technology and process become more advanced and affordable.

1 The Passivhaus retrofit standard, or Ener PHit, is an adapted version of Passivhaus for retrofit projects. For further information please see: Passive House Institute. *EnerPHit: Criteria for Residential-Use Refurbished Buildings*. 2011.

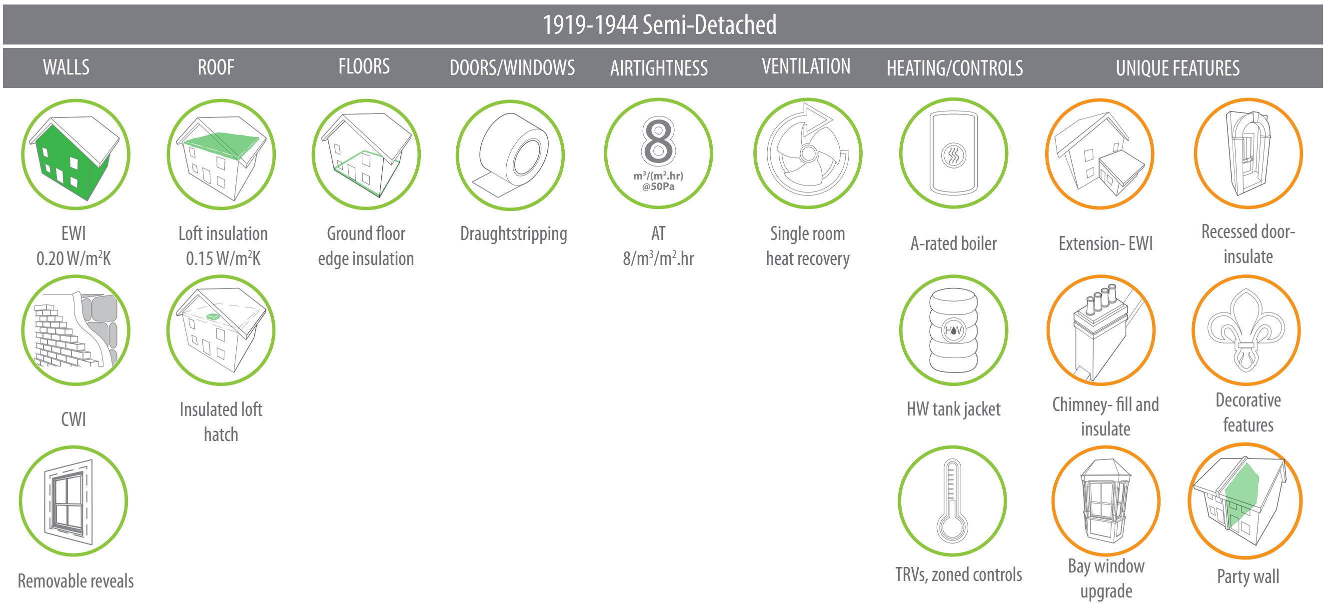


Figure 10. Whole house Retrofix package for 1919-1944 semi-detached dwelling. Unique features are highlighted by orange circles.

Which properties are the likely targets for mass retrofit?

House types for mass retrofit should be targeted not only on their frequency of occurrence but also on their impact on overall carbon emissions. When matched with the early adopting customer types discussed previously, a hierarchy of first mover house / occupant potential can be developed.

While, the energy saving potential will be higher from pre-1919 properties in general, our recommendation is to start with the customer and target properties that are owned by those open to retrofit as a first step.

The target group of house types is based on the number of properties and their energy consumption/carbon dioxide emissions.

How will mass retrofit impact aesthetics of properties and streetscapes?

External Wall Insulation (EWI) is a key element for both RetroFix and RetroPlus packages, and will have a major visual impact on neighbourhood streetscapes. The key stakeholders in this are LA planners and Town and Country Planning Association (TCPA). The following measures can be explored to reduce the impacts of EWI:

- Examples of good practice to help mitigate planners and consumers concerns
- Varieties of wall finishes and colours to avoid monotony and loss of street character
- Rapid prototyping to re-create external decorative features rapidly and cheaply
- Area design guidelines that present a pattern book of finishes, linked to a supply chain that can provide packages suited to the local architectural language
- Street by street or adjoining house installation programmes to unify building elevations

What are the critical success factors for a mass retrofit rollout?

Customer acceptance is crucial for the success of a mass retrofit programme. Householders need to be aware of and understand energy issues and trust that the key providers in the retrofit supply chain (e.g. retrofit installer/providers) can offer real benefits; aesthetically and functionally as well as energy saving.

The project team suggest that the retrofit of 80% of current properties is the maximum likely to be achieved by 2050; to align with the UK's carbon emission reduction target for the same year. To achieve this level the period up to 2020 must be spent stimulating the market and giving householders confidence that retrofit is a worthwhile investment. Demonstrator projects, mass marketing, service offerings and retrofit open days will be essential to build early demand.

The major challenges beyond customer demand are likely to include:

- Availability of funding and affordability of retrofit measures
- Heritage and aesthetic concerns
- Improved trust in the building industry – ensuring that the image of retrofit is not blighted by poor performance and customer satisfaction.
- Appropriate up-skilling (technical and customer skills)

A suite of 'standardised' measures customised by house-type which follows a hierarchy based on the heat loss parameter of each component will help to simplify householder choice and keep costs low.

06
Where should mass retrofit be focussed?

A number of key areas of inquiry needed to be addressed in order for the project to move forward, including the identification of the different types of dwelling in the UK's housing stock, the energy efficiency of each and the number of walls and lofts that have been insulated. Without this information designs could not be specified, the customer base could not be understood and the potential supply chain for retrofit could not begin to be developed.

A three stage approach was taken to this problem:

- Firstly, the forty different dwelling types present in the UK and their key energy characteristics, were identified from house condition survey data,
- Secondly, the data was examined by the design teams to identify the most suitable types of dwelling for retrofit, and
- Finally, the selected dwelling types were combined with information related to likely occupants.

Stock segmentation

In the initial stage, forty different housing stock types were identified, based on their built form and age using national House Condition Survey (HCS) data for England, Scotland, Wales and Northern Ireland. The archetypes were ranked in terms of prevalence, likely energy consumption and carbon emissions and filtered down to the top 9 house-types which represent over 40% of the UK residential stock. Based on this information, the consortium design team developed retrofit solutions for these property types, as outlined in Chapter 5 of this report.

Pre 1919 Converted Flat
690,000 homes
4,250,000 tCO_2

Pre 1919 Detached
780,000 homes
13,940,000 tCO_2

Pre -919 Mid Terrace
2,090,000 homes
13,450,000 tCO_2

1919-44 Semi Detached
1,920,000 homes
13,820,000 tCO_2

1945-1965 Semi Detached
2,040,000 homes
12,850,000 tCO_2

1965-1980 Bungalow
780,000 homes
4,880,000 tCO_2

1965-80 Low rise flat
1,050,000 homes
3,580,000 tCO_2

1965-80 Detached
1,050,000 homes
9,360,000 tCO_2

Post-1980 Detached
1,840,000 homes
12,720,000 tCO_2

Figure 11. The nine house typologies chosen for further investigation by the project team. Each image includes the dwelling type, the number of homes in the UK and the total annual CO_2 emissions of this type.

The 9 house-types chosen for further analysis cover approximately 47% of the total UK housing stock, with 6 being in the top 10 most frequent house types.

Which properties are the likely targets for mass retrofit?

This list of forty was refined to those considered to be most suitable for mass retrofit. This was based on each house type's impact on overall energy consumption, as well as their frequency of occurrence.

Though it is one of the less frequent typologies (only 780,000 homes) Pre-1919 detached homes are the largest contributor to CO_2 emissions of the 9 chosen house types.

Where do the householder groups live?

The third and final stage of the stock segmentation was to consider which types of householder lived in each property and the frequency of these pairings.

The 1945-1965 semi-detached is the second most frequent house type in the UK, and with three of the four early adopter segments (Older Established, Transitional Retirees, Stretched Pensioners) as the most likely residents it is a sensible typology to tackle.

Specific design and supply chain solutions were then considered in the context of these data, with modelling of these specific combinations helping us to understand how much potential exists for saving energy. For example, the above data tells us that a design solution for a Pre-1919 mid terrace should be made attractive to the Early Enterpriser, and Young Starter groups as there are high numbers of these types of household living in these homes.

To assist in the development of the supply chain, the prevalence of the key dwelling types has also been mapped across the UK. This assists in the targeting of the supply chain by providing potential refurbishment hotspots across the UK. The density of Pre-1919 mid-terraces in England is shown in the figure to the right.

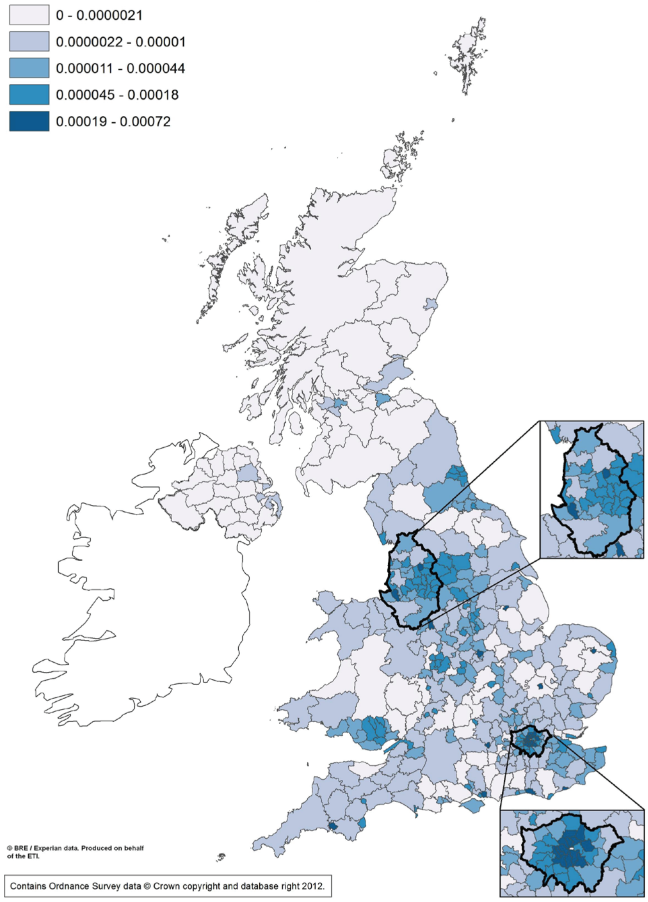


Figure 12. Number of Pre-1919 Mid-Terrace dwellings normalised by Local Authority area.

It is possible to focus our efforts on specific locations as the top house typologies tend to be clustered in 'hotspots' around the UK, typically in areas of high population density.

07

What is the impact of the proposed solutions?

The ETI housing stock energy model quantified the effect of energy efficiency improvements and savings that could be delivered through the retrofit of groups of the UK housing stock for RetroFix and RetroPlus. The retrofit scenarios were assessed at both a 2012 and a 2030 projected base position. The results also include a margin of reduction in achieved savings (from underperformance or comfort take), recognising that maximum improvements are rarely achieved.

Potential savings

The potential savings that can be made from the application of retrofit to the whole housing stock were modelled according to available stock data. For the 2012 scenario, household fuel spend was on average reduced by 49% for the RetroFix and 60% for RetroPlus packages, compared to the baseline. CO_2 emissions were reduced by 33% and 45%, respectively.

In 2030, the reduction in fuel spend was less than 2012 (39% and 49%) due to assumed higher outdoor ambient temperatures but the percentage CO_2 emission savings are comparatively higher due to reduced fuel carbon intensity factors.

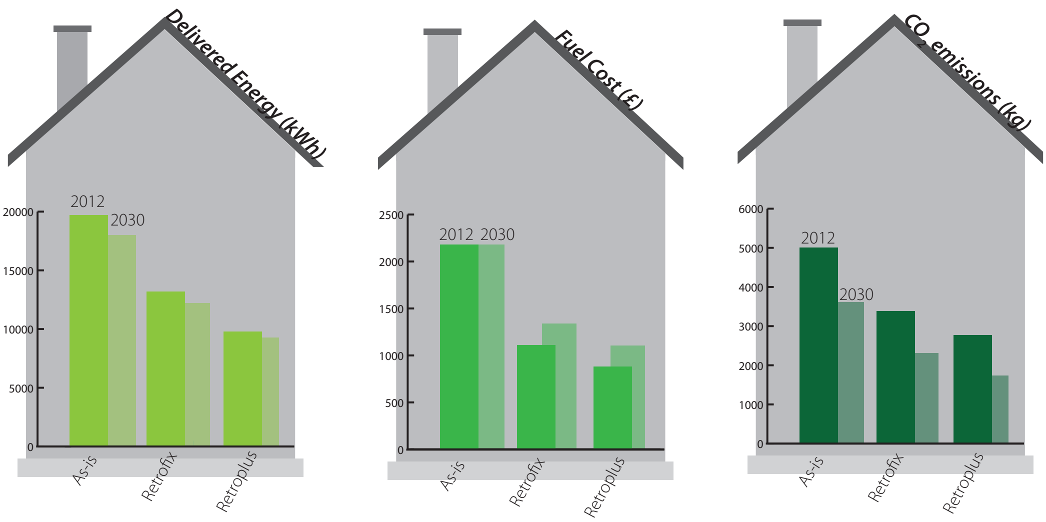
Pre-1919 detached houses showed the greatest reduction in energy use as a result of the retrofit packages.

The range of savings demonstrated broken down by the 20 dwelling/householder types, selected as the best coverage of the householder demographics and type, suggest that the potential CO_2 savings are typically between 20-35% for RetroFix and 30-50% for RetroPlus (although the pre-1919 detached house showed savings of around 54% for RetroFix and 66% for RetroPlus).

The enhanced models predict that RetroFix and RetroPlus packages will reduce, on average, the delivered energy to a UK house by 33% and 50% respectively – taking into account a degree of comfort taking and under-performance of the technology with today's climate data.

The potential for savings in delivered energy consumption ranged between 25-40% for RetroFix and 40-60% for RetroPlus. For primary energy, consumption was reduced to between 300-170 kWh/m^2/annum for RetroFix and 220-140 kWh/m^2/annum for RetroPlus. Heat losses were reduced across all dwelling/household types.

Figure 13. The energy efficiency improvements and savings for RetroFix and RetroPlus for 2012 and a 2030 projected base position. All data is per annum and per property.



The annual carbon footprint of a property is predicted to drop from today's average of 5tCO_2 to 1.7 tCO_2 by 2030 following the installation of Retroplus packages as a result of the planned de-carbonisation of supply and warmer winters.

Mould and overheating risk

Identifying the potential unintended consequences of energy efficient retrofit, such as mould growth and overheating risk, was also a key element of the modelling work.

The risk of mould growth, as calculated by the ETI model, was found to decrease for both RetroFix and RetroPlus scenarios. However, without careful detailing, thermal bridging is likely to occur when insulation is installed on external walls (particularly for internal insulation), which, in turn, may result in surface and interstitial condensation and mould growth. The severity of thermal bridging has been evaluated using the steady-state heat transfer model TRISCO for five alternative EWI installations. It has been found that thermal bridging may occur in some of the details analysed. Both mould growth and thermal bridging models assume precise installation of measures which is a challenge to achieve, particularly on older properties.

If installed correctly, the refurbishment packages will help to reduce cold bridges and the incidence of mould growth.

Analysis of the ETI housing stock model results indicated that indoor summer overheating in domestic environments could potentially be an unintended consequence of the RetroPlus-level energy efficient refurbishment. This is likely to be exacerbated in the future due to climate change (e.g. under 2030 climatic conditions).

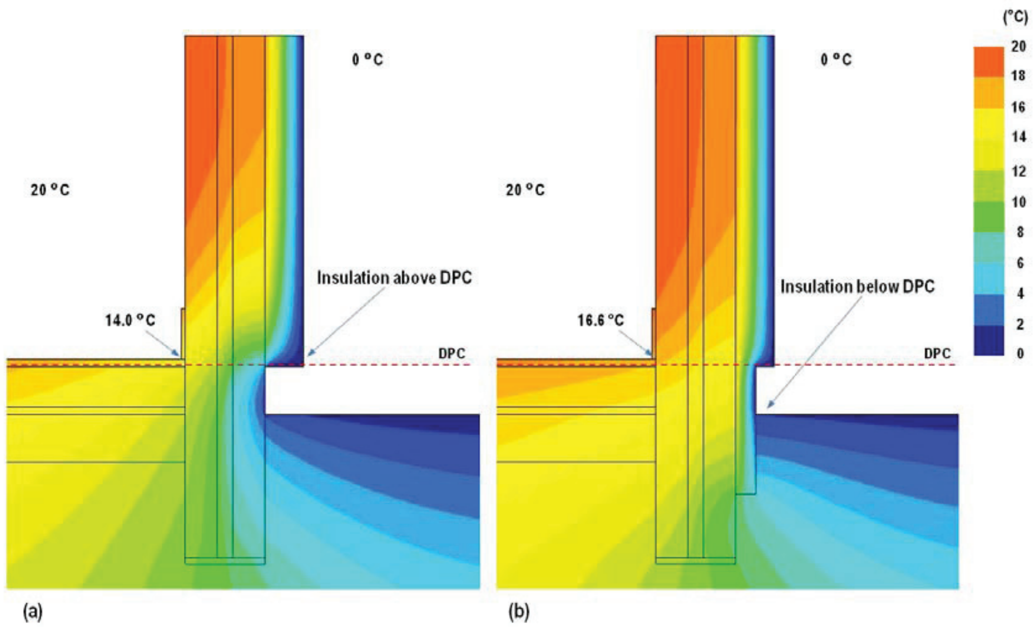
To investigate this further, dynamic thermal simulation of 1,440 combinations of built forms, insulation packages and climate change scenarios, using the dynamic building thermal modelling program EnergyPlus was carried out.

Overheating risk was found to vary as a function of the size of exposed opaque and glazed surface areas (with detached houses and top-floor flats being at higher risk) and the positioning of wall insulation (internally applied insulation generally reducing the amount of available thermal mass and leading to higher increases of internal temperature).

Any mass retrofit programme needs to include measures to prevent overheating, since modeling suggests properties may present a slight overheating risk after RetroPlus under 2030 climate predictions. The overheating risk is considerably greater for internal insulation.

Design recommendations were, therefore, proposed to mitigate the risk of thermal bridging, mould growth and indoor overheating occurring following energy efficient retrofit. For example, for the boundary conditions and construction details modelled, installing insulation below the damp-proof course (DPC), instead of stopping the insulation above the DPC, can considerably increase the temperature of surfaces on the locations studied, and hence significantly reduce the chance of condensation and mould growth, as illustrated in the image below.

Figure 14. TRISCO detail: Internal surface temperatures (°C) with external insulation applied above/below damp-proofing course (DPC).



08

How can retrofit be delivered effectively?

The prime requirement for the mass scale uptake of retrofit is generating consumer demand. One element of achieving this is a capability to 'deliver brilliantly', which will create a highly attractive consumer offering.

As of yet there is no clear retrofit supply chain, as housing energy efficiency measures are provided as part of the broader Repair, Maintenance and Improvement (RMI) sector or DIY market.

The majority of the RMI market is characterised by three approaches:

- *Measure by measure:* Specialists installing single measures (e.g. windows or loft insulation),
- *Jobbing builder:* Tailored approach to the meet owners' requirements which may not involve an architect or specialist designer, and
- *Contractor:* Multiple properties at scale, generally in the rented sector.

None of the above has a systematic process driven approach to meet consumer requirements. As a result, the process suffers from systemic waste (in terms of duplication of effort and wasted material), variable quality (with a failure to meet expectations of energy saving and decorative finish) and inconvenience (as a result of disruption, delays and contract disagreements).

Current retrofit process

There are three key phases of the retrofit process:

- *Survey:* Characterised by high levels of duplicated effort (multiple quotes & surveys),
- *Installation:* Suffers from excessive non-productive time and material waste, and
- *Through-life maintenance:* Offerings are given little consideration in the current market.

Labour effectiveness is the greatest potential improvement with an anticipated 40% reduction achievable across survey and installation with Lean Processes.

Future state design

Rather than seek to improve the current (incapable) supply mechanisms, the team designed new models for retrofit which aimed to meet all customer requirements without duplication, deviation, delay or defects.

The Poly Competent team model is the approach to make single property, whole house retrofit viable.

Key Elements of all new models are:

Whole house systems: To reduce installation programme, cost and associated disruption compared with single measures and multiple installers. Measure my measure solutions also underperform technically because insufficient attention is paid to the interface between measures, or how the whole home will perform.

Poly-Competent Teams: Teams capable of delivering the whole solution with 4 people. The project team define poly-competence as the capability to perform all the requisite tasks for retrofit (across traditional trades of electrician, plasterer etc.) but without the full expertise and cost of a time-served tradesman. These teams meet the consumer preference of a small familiar team and provides a quality outcome as a result of whole house responsibility. In addition the flexibility to balance labour between tasks on site increases productivity, without the need to shift specialist labour between multiple home contracts.

Lean Supply Chains: In order to improve retrofit efficiency, there will need to be a lean process and flow of materials. This will include the development of pre-prepared materials, as work completed off-site will help to reduce disruption, site error, time, weather dependence and cost. This should also involve the development of a single delivery route to site with returnable packs to minimise distribution cost.

In conjunction with pre-prepared materials, standard packages and products will need to be produced in order to reduce the cost of variety through manufacturing set-up, stock-holding, and specification/ installation error. Costs will also be reduced through the creation of 'pull-systems' , where supermarket style data exchange is able to generate true demand for suppliers, reducing stock, distribution and damaged material costs.

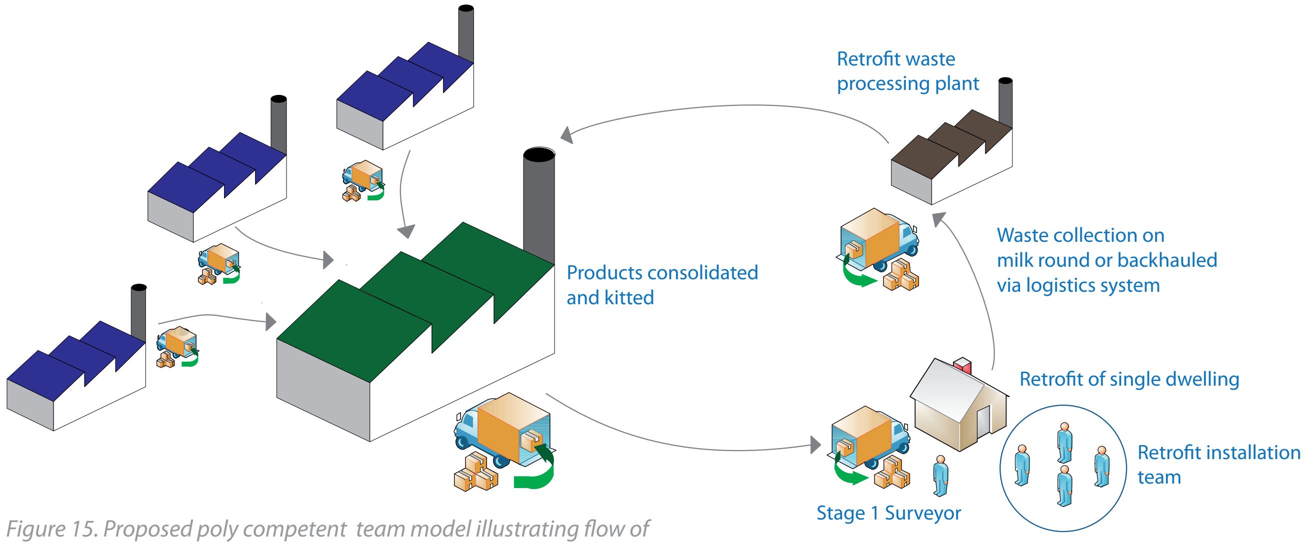


Figure 15. Proposed poly competent team model illustrating flow of goods and services.

Alternative commercial models

As a result of 70% of UK housing being owner occupied, retrofit solutions need to appeal to individual householders. Social tenants are an easier group to access through their landlords, although much has been done in this sector already. Private landlords are the most disparate group and so difficult to categorise into a market.

Alternative models of supply will remain but the potential for a Disruptive Franchise style solution offers an exciting prospect to accelerate the growth of the retrofit market.

Contractors or National Providers are the most likely to serve the multiple property Social Housing market, both currently and into the future. These are characterised by:

- Street by street installation: Single contract, multiple property programme
- Cost saving through economies of scale: bulk buying, installer overhead spread over many properties and installation teams.

National Providers & Retail RMI will need to adapt to meet consumer requirements in the Owner Occupier market with:

- A 'whole house' approach: eg. integrated window & insulation offerings
- A focus on 'target cost' to meet the £10,000 expectation with confirmed energy saving.

The Franchise model is developed to satisfy the consumer demand for locally based providers with the back-up from a larger organisation as franchisor. Two elements are essential for this to succeed:

- Standard packages of work, customised for each home for which installation teams can be trained and perfected,
- One or more branded Franchisors to invest and give market confidence, scale, integrated supply and technical support to local franchise operators.

Research findings & peer review

A crucial part of the Retrofit supply chain design was a regular peer review. This feedback both challenged, reinforced and refined the ideas.

The hierarchy of requirements from the supply chain as outlined by the Consumer research was led by:

- Cost (affordability & payback) – Details in Chapter 10,
- Trust that it will be a quality job and deliver expected savings, and
- Low disruption in time and inconvenience.

Overall, feedback was generally conservative, with little recognition of any need for change. A whole house approach was welcomed both technically and commercially (larger projects are seen as more profitable). Most interestingly, although Poly-Competence is recognised as step forward in productivity and service, there are many vested interests in maintaining trade based skill silos. However, there was consensus that a whole house offering for under the £10,000 target was optimistic.

The Green Deal is seen as an important enabler for encouraging retrofit, but providers are concerned that demand will still be low. As a result investment in capability is likely to be initially cautious.

New approaches are expected to deliver at least a 30% saving over current & Green Deal expected costs.

As a desk based research programme the supply chain proposals have not been tested practically, but the peer review did not identify intractable obstacles.

An integrated supply chain with single delivery and combined waste will almost halve material distribution cost.

09
How does policy need to change?

Government funding

Many householders have been aware of previous energy efficiency policies, but uptake has been low. How do we overcome the householder inertia? Can policy changes and incentives play a part? This project has undertaken a wide ranging consultation process to identify polices that will stimulate the market to counter low take up levels, to remove process roadblocks and to help to guarantee safety for those involved in retrofit installation.

The Government's cornerstone programme is the Green Deal which is accompanied by the Energy Company Obligation (ECO). The latter will replace the current CERT and CESP schemes which provide basic energy efficiency measures, with one in which a whole range of low carbon retrofit measures can be funded using long term finance that is paid back through the householders' electricity bills. The policy will stimulate those who want to do the "right thing" by avoiding upfront costs, but the net savings on the fuel bills is likely to be modest.

The ECO scheme helps to fund certain types of retrofit work in low income and vulnerable households and/or hard to treat homes, but it would be desirable to find a way to stimulate the rest of the population. This could be provided by two key policy initiatives which came out of the project's consultation process; possibly supported by a change in VAT regulations.

Stamp duty and EPC

The first is to tilt Stamp Duty in a similar way to Vehicle Excise Duty (VED). VED is based on carbon emissions and in a similar way Stamp Duty could be based on the Energy Performance Certificate (EPC) band. People buying homes with a poor EPC rating would pay more and those with a good EPC less (or even nothing). To obtain a tax rebate, new home owners would then have 12 months in which to improve the dwelling and generate a new EPC. The policy would be able to adjust the rates of Stamp Duty charged to maintain revenue neutrality to government. The scope to stimulate the market is greatest for properties over £250,000.

The second policy would be to set an EPC floor, so that poor performing properties could not be let or sold. The power to set such limits is already in existence in Scotland. In England this is limited to Private Rental and will be a requirement from 2018. To soften the impact of the policy on hard pressed sellers it would be prudent to make sure that the duty to upgrade the property could be transferred to the buyer, who would have 12 months to do the work or be fined. For the policy to have serious impact it would be necessary for it to apply to both F and G rated properties.

Adjusting Stamp Duty dependent on a dwelling's carbon emissions could significantly boost the uptake of retrofit by an estimated 5M properties, over 15 years.

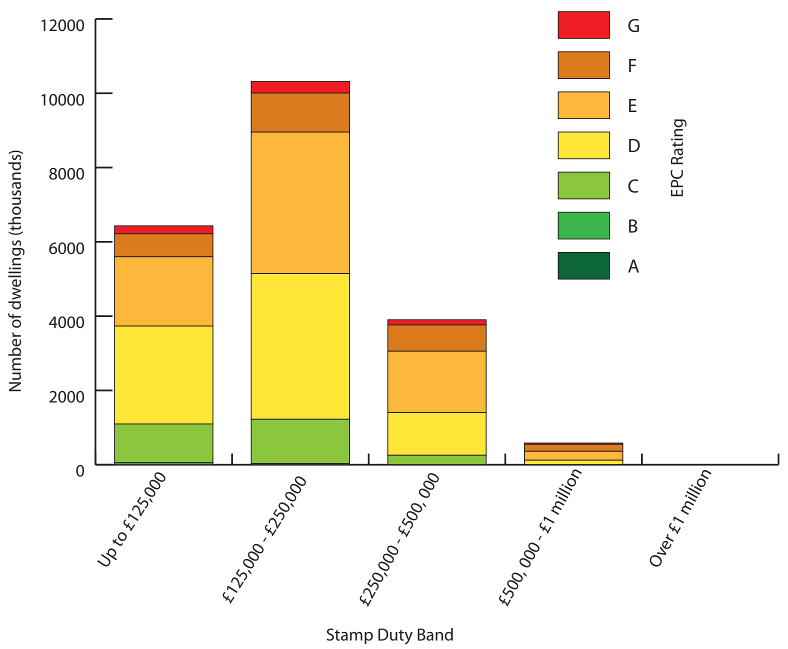


Figure 16. EPC ratings of homes in the UK by Stamp Duty Band.

A minimum EPC of E for all tenures could boost the uptake of retrofit by an estimated three million properties, over 15 years.

Both these policies could be further stimulated by a change in VAT regulations. Ideally, all refurbishment work, whether directly linked to energy efficiency or not, should be charged at the same low rate of 5%. This would encourage energy efficiency to become part of general refurbishment albeit with a modest impact on a retrofit market. So although the policy is desirable it could wait for a better financial climate to emerge.

However, there are two obstacles. the first of which involves HM Treasury concerns over reduced VAT revenue. The second relates to EU limitations on the use of VAT to influence markets. As a result the prime objective should be to encourage use of the current reduced VAT on energy efficient products by raising awareness amongst installers and simplifying the process for claiming the reduced rate.

Figure 17. EWI installed on one side of semi-detached property. Source: www.building.co.uk

Consequential improvements

External wall insulation can require planning permission which is a barrier to householders wishing to install it. Urgent attention should be given to making it Permitted Development with exceptions for Listed and Conservation Area properties (this is already the case in Scotland) but guidance should also be prepared in relation to the technical and aesthetic impact of EWI and the associated potential financial devaluation of homes.

With around 200,000 extensions and loft conversions each year it is important for a Consequential Improvement policy to link home improvement and energy saving.

A "consequential improvements" regulation in England would, in the words of the Committee on Climate Change, be a "useful lever for addressing risks of delivering loft and cavity wall insulation under the Green Deal." It would also help any form of energy retrofit.

Making External Wall Insulation Permitted Development in England will give planning consistency and aid mass scale retrofit.

Other aids to mass retrofit would be:

- To have a central database that would help to target marketing and ease home assessments, and
- Tax breaks to encourage the setting up of poly-competent team companies, if they were slow to form.

Health and safety

In the area of health and safety it would be prudent to have retrofitted homes install a carbon monoxide detector and this could be easily be included in the next Buildings Regulations update. With regard to safety at work greater emphasis needs to be given to enforcing existing regulation, especially fast tracking fatality prosecutions and reinforcing the responsibility of all on site for the safety of themselves and others.

The franchised poly-competent team brings the challenge of ensuring health and safety at work is seen as a priority, which is often not the case with small businesses today. However, heavy centralised regulation risks over-burdening smaller businesses. As such, a pragmatic, light touch health and safety culture is required.

Health and safety at work needs attention at the small business level, ensuring it is taken seriously to reduce current accident levels, but without over-burdening SMEs.

Warranties

In an area outside of Government it would be desirable to see warranties provided for refurbishment. The pre-requisites to this are trained operatives and standard installation procedures. Good work is being done in all of these, including the introduction of PAS2030 to cover Green Deal work; however there is no current warranty provision. Commissioning a provider may be best undertaken by the Green Deal Finance Company or Green Investment Bank.

10
What is the value and cost of retrofit?

There are three major drivers for retrofit:

1. *Environmental:* Reducing demand to meet UK Climate Change Commitments,
2. *Social:* Reducing fuel poverty and providing basic energy needs, and
3. *Economic:* The cost of investment must be equal to or lower than the sum of the avoided costs.

How can we put a value on retrofit?

To put a financial value on retrofit the project team looked at two levels:

1. The national economic level using the DECC IAG Valuation tool
2. Householder level using 'payback period' at two discount rates.

The DECC IAG toolkit is a mechanism to assess the economic impact of energy saving policy and projects. Using the predicted annual energy saving (kWh), in Chapter 7 by house-type, with anticipated take up rates of retrofit from 2014 to 2050, an assessment of the break-even investment in retrofit per property can be made.

The break-even investment (target cost) have a range of £3,750 to £26,000 for RetroFix and £7,000 to £36,000 for RetroPlus.

Using retail energy pricing (£/kWh) forecast from the IAG toolkit, linked to the target costs above, we can demonstrate that the payback period is 11-14 years for RetroFix @3.5% Discount Factor (Government cost of finance) and 14- 20 years @ 7% (expected for Green Deal).

This is unlikely to be a compelling return on investment for householders based on their current expectations of the hassle and disruption of building work.

The break-even cost of RetroFix varies between £3,750 & £26,000 depending on property type and current energy consumption.

Costs

The retrofit delivery approaches described in Chapter 6 aim to minimise costs, whilst improving trust and reducing disruption for the householder. The anticipated 30% reduction brings future costs down to:

- £7,500 - £21,000 for RetroFix, and
- £15,000 to £31,000 for RetroPlus

At more than double the target costs, this highlights the scale of the cost reduction challenge if retrofit is to be valuable based on financial payback alone.

Significant progress has been made on retrofit costs reducing whole house RetroFix packages by 30% versus current costs.

The Direct costs cover:

- House survey 1 & sale process
- Survey 2 & installation labour
- Material: Manufacture and distribution

The desk based process designs indicate the following potential cost reductions:

- 40% labour saving
- 45% reduction in distribution cost
- 10% reduction in material cost

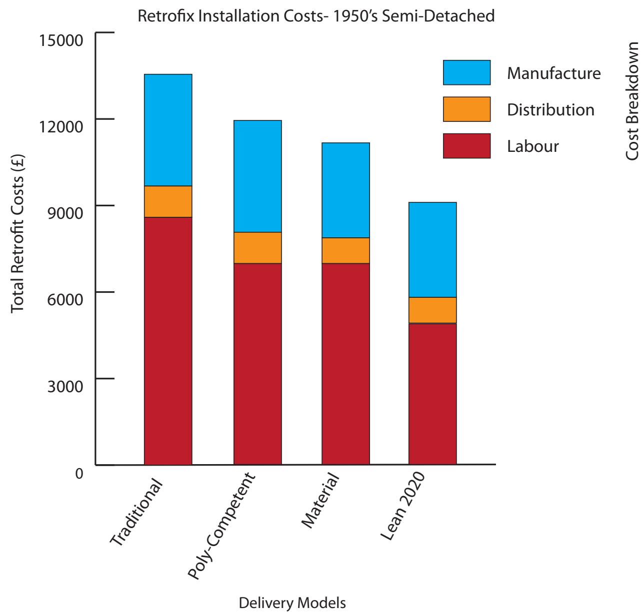


Figure 18. Breakdown of Retrofix costs for a 1950's semi-detached home for different delivery models.

For average resident energy consumption, even with reduced retrofit cost, neither RetroFix or RetroPlus will give the householder a satisfactory payback period.

In addition to the direct costs there are significant challenges for stimulating the market and mobilizing the retrofit industry:

- *Marketing / Awareness:* Surveys software and documentation
- *Solution Design:* New delivery models
- *Sales Process:* Legal frameworks and documents
- *Material Provision*: Specifications and demand management
- *Install*: Skills, insurance and health & safety

The total indirect transition costs for the initial retrofit at scale are estimated at £50 million, the bulk being focused on consumer marketing and awareness.

How big is the cost gap?

Table 1 shows the significant challenge to achieve an attractive offering with analysis based on payback alone. There are 3 potential mechanisms which will shift the balance:

- *Reducing Intervention Cost:* The cost of whole house Retrofix package for a 1950 semi-detached property would need to reduce by another 59% (around the current cost of double glazing alone),
- *Increased Saving:* The project has taken account of past under-performance of actual versus anticipated energy saving. Although cautious; proposing a >50% saving from RetroFix to hit the target cost would not be credible, and
- *Above Average Energy Users:* Pre-1919 detached results show that current annual energy use has a major impact on break-even investment and payback.

These will play a part, but mechanisms are required to make retrofit attractive to the mass market without guaranteed payback::

- Improved aesthetics and property values: As experienced with double glazing in the 1980's – valued more highly by householders than the energy saving achieved,
- Linking retrofit with other triggers for home improvement to increase perceived value, and
- Shift the value balance with policy incentives for investment or penalties for poor energy performance.

The following factors should not be adjusted to allow cross project assessment:

- Cost of capital
- Energy price forecasts

UK National perspective

Other factors come into play at the national level as indirect costs and benefits of Retrofit have an impact, including:

- Avoided infrastructure investment,
- Savings in health and social care as a result of improved comfort, and
- Economic activity: Generating UK first mover advantage for potential export.

This project has not attempted to quantify these impacts, but they should be borne in mind at the whole system level.

Table 1. Break Even Investment by house type: Based on IAG Valuation Tool.

House Type	Current MWh/yr	Delivered Energy Saving		Break Even Investment	GWh Saved-2020	GWh Saved-2050	Payback @3.5%	Green Deal Cost	Future Cost
1945-1964 Semi-Detached	18	Fix	30%	£3,750	811	8,828	11	£14,525	£9,058
		Plus	51%	£7,000	1,379	15,008	12	n/a	£13,815
Pre-1919 Mid-Terrace	20	Fix	38%	£6,000	937	12,744	13	£11,542	£7,778
		Plus	56%	£9,500	1,380	18,780	14	n/a	£13,470
1919-44 Semi-Detached	23	Fix	37%	£6,700	1,051	13,199	12	£14,525	£9,058
		Plus	58%	£11,000	1,648	20,691	13	n/a	£13,815
Post 1980 Detached	24	Fix	29%	£5,200	825	10,358	12	£14,520	£12,464
		Plus	43%	£8,300	1,223	15,358	13	n/a	£19,682
Pre-1919 Detached	60	Fix	51%	£26,000	1,179	18,496	14	£16,203	£15,004
		Plus	68%	£36,000	1,571	24,661	14	n/a	£21,567

11

Summary of Key Findings

General Conclusions

- The market and press reaction to the initial rollout is crucial to future success. Early failures in performance, service or cost will be very difficult to recover from.

- There is significant potential from linking low carbon retrofit with other large scale domestic changes: flood protection, smart meter rollout, water company initiatives and IT, electrical or gas infrastructure repair and upgrade.

- Although a street by street approach is considered by some to be more effective, the project team can see limited potential to engage consumers in the dominant Owner Occupier market. In addition a correctly designed process should deliver equally cost effectively for single properties.

- Retrofit should enable a general improvement in the currently poor condition of UK housing stock, or at least reduce the rate of further decline.

- Mass scale retrofit models can support and be encouraged by other initiatives such as Energy Company Obligations (ECO) and the Green Deal if presentation to the public is clear and objectives are seen to be aligned.

Figure 19. An example of a 1960's semi-detached home post-retrofit.

04 What does the householder want?

- Widespread mistrust of the trades remains a significant barrier to the uptake of retrofit as will any retrofit over £10, 000.

- A preference for personal recommendations from friends and family in choosing retrofit service providers highlights the need for customer engagement and marketing to harness the power of personal networks. scale.

- Many customers believe they have already retrofitted their homes due to small-scale energy efficiency improvements and have become accustomed to utilities or Government supplying these works for free.

- 'Early adopter' segments are similar enough to design retrofit roll-out solutions that will appeal to all four early adopting householder segments groups – focusing on local trades and improved advice.

05 What are the ideal solutions?

- "Do it once and do it properly" was the key to the generation of whole house packages

- A suite of 'standardised' measures customised by house-type which follows a hierarchy based on the heat loss parameter of each component will help to simplify householder choice and keep costs low.

- Two levels of intervention have been proposed: Retrofix and RetroPlus with the latter being the recommended option. A PassivHaus standard RetroMax as the ultimate target when technology and process become more advanced and affordable.

- The target group of house types is based on the number of properties and their energy consumption/carbon dioxide emissions.

06 Where should mass retrofit be focussed?

- The 9 house-types chosen for further analysis cover approximately 47% of the total UK housing stock, 6 are in the top 10 most frequent house types.
- The 1945-1965 semi-detached is the second most frequent house types in the UK (over 2M homes) and a significant contributor to CO_2 emissions. Three of the four early adopter segments are the most likely residents of this house type, making it a logical typology to tackle.
- Though it is one of the less frequent typologies (only 780,000 homes) Pre-1919 detached homes are the largest contributor to CO_2 emissions of the 9 chosen house types.
- It is possible to focus our efforts on specific locations as the top house typologies tend to be clustered in 'hotspots' around the UK, typically in areas of high population density.

07 What is the impact of the proposed solutions?

- Pre-1919 detached houses showed the greatest reduction in energy use as a result of the retrofit packages.
- The enhanced models predict that RetroFix and RetroPlus packages will reduce, on average, the delivered energy to a UK house by 33% and 50% respectively – taking into account a degree of some comfort taking and under-performance of the technology with today's climate data.
- The annual carbon footprint of a property is predicted to drop from today's average of 5tCO_2 to 1.7 tCO_2 by 2030 following the installation of Retroplus packages and as a result of the planned de-carbonisation of supply and warmer winters.
- Installed correctly, the refurbishment packages will help to reduce cold bridges and the incidence of mould growth.
- Mass retrofit needs to include options to prevent overheating, since modeling suggests properties may present a slight overheating risk after RetroPlus under 2030 climate predictions. The overheating risk is considerably greater for internal insulation.

08 How can retrofit be delivered effectively?

- Labour effectiveness is the greatest potential improvement with and anticipated 40% reduction achievable across survey and installation with Lean Processes.
- The Poly Competent team model is the approach to make single property, whole house retrofit viable.
- Alternative models of supply will remain but the potential for a disruptive Franchise style solution offers an exciting prospect to accelerate growth of the retrofit market.
- New approaches are expected to deliver at least a 30% saving over current & Green Deal expected costs.
- An integrated supply chain with single delivery, combined with site waste removal, will almost halve material distribution cost.

09 How does policy need to change?

- Adjusting Stamp Duty dependent on a dwelling's carbon emissions could significantly boost the uptake of retrofit by an estimated 5 million properties, over 15 years.
- A minimum EPC of E for all tenures could boost the uptake of retrofit by an estimated 3 million properties, over 15 years.
- With around 200,000 extensions / loft conversions each year it is important for a Consequential Improvement policy to link home improvement and energy saving.
- Making External Wall Insulation Permitted Development in England will give planning consistency and aid mass scale retrofit.
- Health and safety at work needs attention at the small business level, ensuring it is taken seriously to reduce current accident levels, but without over-burdening SMEs.

12

Recommendations for Future Work

This report summarises the results of a largely paper based research project which has had to make many assumptions about the practical, behavioural and technical problems of mass retrofit for a very diverse mixture of occupants and dwelling types.

These assumptions will need to be tested in the field before a mass multi-billion pound programme is rolled out in the UK. If 2030 targets are to be met, a series of field trials will need to be undertaken whereby the assumptions can be tested, unintended consequences identified and appropriately treated, supply chains developed and costs reduced. For this to occur in a timely manner appropriate learning cycles from field trials will need to be developed.

The project team's recommendations for further work fall into two categories:

- Practical Field projects to trial, pilot and review previous programmes, and
- Academic and Market research to assess and predict the social and economic impact of retrofit while identifying needs and opportunities for new technology.

Figures 20 and 21. Resident engagement and retrofit work.

Practical field trials

The proposed Field Projects are at varying levels of scale and encompass 3 programmes:

- *10 Homes Pilot*: A single home RetroFix and RetroPlus for each of the top five house type and consumer combinations to set the benchmark of material and labour cost. This will include a time & materials study to confirm the potential saving. This pilot is only necessary if there are obstacles to launching the 100 home project in 2012.

Timescale: Three months from October 2012 or March 2013
Investment: £250, 000

- *50 Homes Survey of each House-Type*: As a precursor to 100 homes retrofit to give a measure of the diversity of stock within a particular house-type and locality. A detailed survey will be completed for each of the top house types identified in the Homes Pilot above. This will take place across the UK in order to address regional variations and vernacular styles, construction types, house positions on plots, party wall details, local policy requirements, etc.
- The survey will assertain the potential for the replication of solutions on national scale or whether regional, or part-solutions, are required. This work could also include current energy use data logging and a user behaviour study.

Timescale: February-March 2013
Investment: **£375,000** (50x £1,000 survey + £50,000 programme design and management + £25,000 architectural fees + £200,000 user behaviour data logging)

- *100 Homes Retrofit:* A rapid practical, programme designed to test the survey and installation models by using a poly-competent team to iteratively RetroFix and RetroPlus 20 homes of the same house type over an 18 month period. This will demonstrate the achievable reduction in time and materials, while also gathering valuable pre- and post-occupancy data to assess the energy performance improvement and any associated technological and environmental impacts on the homes. Short term monitoring should occur over a 12 to 24 month period. The data collection will also be designed to add to the ETI model and the user behavioural aspects in particular. Please see Appendix A for further detail.

Timescale: 18 months from October 2012 or March 2013
Investment: £4 million, 50% funded by property owner

Market and academic research

Future programmes, outside the practical field trails suggested above, should include investigations into the following:

- *The impact of mass retrofit on property value:* For the retrofit market to grow there needs to be recognition of a value premium on more energy efficient homes. Conversely, there are reports from Germany that PV installations have devalued properties. A thorough understanding of property market drivers and influencers would be hugely valuable. It would be beneficial to link this with the challenge of marketing energy efficient new homes, and transfering the knowledge of this market to retrofit.

- *Solid Wall Property Heat Loss Review:* Recently concerns have grown that the underlying assumptions for the heat loss through solid walls has been overestimated. Further research and analysis to reduce the uncertainty in the baseline case for solid wall retrofit

- *Planning policy:* Review of built EWI projects to understand which projects have needed planning permission and what factors required it - local authority location, dwelling position, EWI proposal etc. Impacts such as cost and programme implications should be quantified to assess the planning burden and identify opportunities for improvement.

  Health and safety legislation has reduced accidents on large construction sites, but has had minimal impact for the SME sector. Revising CDM regulations with a focus on organisations employing less than 10 people will have a positive impact and also ensure mass scale retrofit is not undermined by an image of poor safety.

- *Material availability and innovation:* With a range of desirable innovations identified in this project; research into the development timescales and future costs of new products and technologies would be a valuable addition to the body of knowledge. A key challenge of this work will be to make the assessment both technology and producer agnostic; whilst greatly reducing the time and cost of gaining certification for new solutions. This will avoid the current concerns of large players dominating the Green Deal product landscape, at the expense of innovation

Technical peformance

Some solutions and products have had only limited application in the UK housing stock and their long term benefits, costs and unintended consequences are not well understood. Examples include the performance of MVHR and Heat pump installations over time and the impact of internal wall insulation on indoor air quality and building fabric. Quantification of performance these solutions would be usefully linked to the proposed 100 Retrofit Revisit.

Long term monitoring, ideally over a five year period, of the technologies installed in the 100 Homes Retrofit programme should be undertaken. This will help to better understand the maintenance needs of technology, customer acceptance and the differences, if any, between expected and actual performance.

Thermal simulation models

Thermal models are only as good as the data that underpins the algorithms. It is proposed that the data collected as results of field trials must be structured in a way that it can be included in the development of future energy models in order to improve thermal models of retrofit.

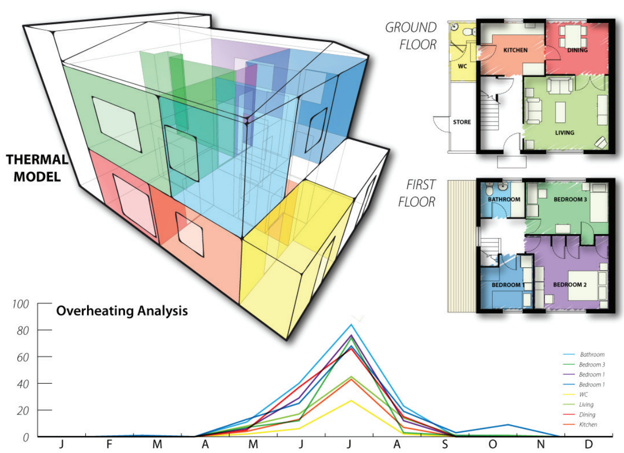


Figure 22. An example of a thorough overheating analysis.

Appendix A: 100 Homes Retrofit Project

Vision

Research carried out through TSB Retrofit for the Future & ETI Thermal Efficiency project has demonstrated the need for deeper interventions to save significant energy through retrofit of domestic buildings. Three elements are crucial if a retrofit market is to develop:

- Tackle the whole house as a system to achieve >30% reduction in energy and CO_2 emissions and demonstrate that reduced energy consumption is consistently achieved,
- Engage householders with attractive solutions with rapid timeframes and minimal disruption, installed by a small local team of poly-competent specialists – with slick and reliable service, and
- Develop lower cost offerings – Today the investment required is double than what the customer is willing to pay.

As a step towards delivery at scale there is a need to validate that the innovative solutions can meet these requirements and can be replicated across multiple properties.

This project proposes to tackle this with a 5 cycle retrofit pilot is proposed in which insight from each phase is fed into the next to improve the outcomes.

Objectives

To demonstrate the potential for mass-scale retrofit by taking the top 5 distinctive house types from the ETI project and deliver RetroFix (Basic level whole house intervention approx. 30% saving) and RetroPlus (Best cost-effective solution approx. 50% saving):

- Collect energy data before and after intervention which can further develop the understanding of changes in user behaviour post retrofit. This will also help refine the individual dwelling modelling tool and by inference the stock model.
- Demonstrate the potential for a step-change improvement in the retrofit proposition with 5 cycles each of each intervention – sequentially. Capturing learning, at each iteration, to refine the Quality, speed, disruption, usability & technical performance of Retrofit.
- The process will also further engage installers and supply chain players in confirming the viability of new franchise models.

Team

- Team co-ordination and project lead: Total Flow
- Academic research input: UCL
- Detailed solution design: PRP
- Supply chain & Process design: Total Flow
- Programme management: PRP
- Partner district: TBA

Delivery Partners
- Installation: Contractors or retail installers
- Materials & logistics

Property / Occupant Mix

This mix is dominated by Owner occupiers who may be more difficult to engage at this stage but our ambition should be to do so:

Pre 1919 Detached: Affluent, Semi-Rural, 55yrs+, Owner-occupier

Pre 1919 Mid Terrace: Affluent, Urban, 30-50yrs , Owner-occupier

1945-1964 Semi Detached: Low income, Urban, 65+, Social renter, some Owner-occupier

1919-1944 Semi Detached: Moderately Affluent, Urban 60yrs+, Social renter & Owner-occupier

Post 1980 Detached: Affluent, Suburban, 60yrs+, Owner-occupier

Programme

Month 1-3 (Stretch target: October 2012 -December 12)

- Confirm partner district and engage owners/ occupiers
- Develop data collection analysis and modelling programme.
- Design programme and iterations
- Prepare installation & supply chain
- Commence survey process

Month 4-6 (Stretch target: January 2013-March 2013)

- Deliver cycle 1
- House types 1-5: 2 properties of each retrofitted in 13weeks

10 homes 3 months – by 5 teams of 4 + observers.

Month 7-9 (Stretch Target: April 2013-June 2013)

- Deliver cycles 2, 3, 4

30 homes in 3 months

Month 10-12 (Stretch target: July 2013-September 2013)

- Deliver cycle 5
- Deliver 6 properties of each house type (flying solo) in rapid succession (6 weeks)
- Review challenges: - in process and adapt approach in real time (1 week)
- Deliver 5 properties of each house type (flying solo) (6 weeks)

60 homes in 3 months
Total: 100 properties in 12 months

Month 13-15 (Stretch Target: October 2013-December 2013)

- Post intervention consolidation of findings and dissemination report for consumer engagement, solution design and supply chain models.
- On-going collection of household data.

Month 15-18 (Stretch Target: January 2014- March 2014)

- Collect second winter of post-retrofit data for cycle 1
- Collect first winter of post-retrofit data for cycles 2-5

Month 19-20 (Stretch Target: April 2014- May 2014)

- Collation and presentation of results.

Funding proposal

- Retrofit work @ £10k Target Cost provided by 'districts': **£1 million**
- CERT/ ECO Funding via Energy Company: **£1 million**
- Match funded by TSB: **£2 million**

- ETI in support of Smart Systems & Heat Programme
- Green Deal pilot fund – street by street demonstrators
- Green Deal finance
- ECO – Community carbon saving and Affordable Warmth

Outline Costs

Core team programme design and management over 2 years	**£300,000**
Pre and post retrofit data design, technology and analysis:	**£500,000**
Transformation cost labour and materials	**£2 million**
Supply chain design, monitoring and optimisation	**£400,000**
Design detailing input over 18 months:	**£200,000**
Enabling investment for product trials / specialist equipment:	**£300,000**
Consumer engagement & liaison-5 FTE equivalent @ MGT:	**£200,000**
Travel & Expenses- 20 people x £400/ mth + 12 :	**£100,000**
Total:	**£4 million**

Challenges to be considered:

- Speed of getting mobilised: This has ambitious programme timing but with the objective of rapid practical results to inform other work.
- Regionality: Is it better to focus on one geographic region to create a focus or to disperse the 5 house types across the UK?
- Linking with Green Deal finance and quality assurance mechanisms in a positive way without compromising outcomes.
- IP ownership: The premise is that the outputs would be public domain and any arising IP would be jointly owned by finders and project partners. Is this viable?
- Warranty insurance and construction liability: With new solutions it needs to be clear who / how premature failure can be rectified post project completion.

Appendix B: Project Deliverables

Work Package 1: Single Dwelling Model

1.1	Identify Energy Models
1.2	Review and Assess Models
1.3a	Core Individual Dwelling Model: Functional Specification
1.3b	Core Individual Dwelling Model: Alpha Version
1.3c	Core Individual Dwelling Model: Beta Version
1.4	Validity of Core Model Testing
1.5	Refine Model based on Design and Cost Data
1.6	Technical Report and Training

Work Package 2: Housing Stock Model

2.1a	Stock Archetypes
2.1b	Stock Archetypes Report
2.2a	Costing Model
2.2b	Costing Model Report
2.3a	Documentation
2.3b	Validation
2.3c	Uncertainty
2.4	UK MARKAL Modelling
2.5a	Scenarios
2.5b	Indoor Overheating
2.5c	Thermal Bridging
2.6	Local Area Maps
2.7	Technical Report and Training

Work Package 3: Technical Solutions

3.1	DfX Workshop
3.2	Retrofit and Refurbishment Case Studies
3.3a	Technical Solutions Matrix
3.3b	Whole House Solutions
3.4a	Virtual Refurbishment
3.4b	Single Dwelling Implementation Plan
3.5	Mass Implementation Plan
3.6	Cost & Performance
3.7	Synthesis Report

Work Package 4: Supply Chain

4.0	Existing Supply Chain Review
4.1	Draft Supply Chain Design
4.2	Supply Chain Scenarios
4.3	Target Supply Chain Scenarios
4.4	Detailed Supply Chain Workshop
4.5	Change Management Process and Plan
4.6	Market Readiness Report
4.7	Summary Report

Work Package 5: Customer Engagement

5.1	Defining the Customer
5.2	Customer Segmentation
5.3	Customer Engagement Exercise 1
5.4	Customer Engagement Exercise 2
5.5	Synthesis Report

Work Package 6: Policy

6.1	Existing Policy and Regulation Review
6.2	Policy and Regulation Workshop
6.3	Desktop Review and Road Test
6.4a	Policy Change Roadmap Workshop
6.4b	Policy Recommendations
6.5	Technical Report

Work Package 7: Health and Safety

7.1	Benchmarking and Gap Analysis
7.2	Health and Safety Approach
7.3	Technology Opportunity Workshop
7.4	Site Specific CDM

OPTIMISING THERMAL EFFICIENCY

OF EXISTING HOUSING

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