Can market transformation approaches apply to service markets? An investigation of innovation, learning, risk and reward in the case of low-carbon housing refurbishment in the UK

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Abstract
Market Transformation (MT) has a long history in product markets, improving the energy efficiency of stocks of energy-using appliances through research, minimum standards, energy labels, incentives, procurement, competitions and stakeholder networks. Attempts to apply MT to buildings have failed to fully take account of the difference in nature between appliance markets and buildings, most noticeably in relation to the refurbishment of existing buildings, which is inherently labour-intensive and bespoke: products and materials are used in transforming buildings, but the tasks involved and the resulting energy performance are related to service quality at least as much as to product quality. Disappointing results from compliance checks confirm that quality of service delivery remains too low.

Case studies of low-carbon housing refurbishment in the UK reveal important processes that need to be understood and accommodated in policy design if MT approaches in this service market are to succeed. These include the sources of innovation in project-based industries; methods and reasons for acquiring new skills and knowledge; technical risks associated with doing low-carbon refurbishment work; and the role of policy in simultaneously stimulating supply and demand. Continual feedback is needed between training, standard-setting and compliance checks to bring design and observed performance closer together. No institutional infrastructure exists for such an enterprise.

In theory, MT principles can be applied to buildings, but each principle needs to be re-interpreted to take account of the markets in question. This is a significant challenge for the capacity of policy-making institutions, just as it is a challenge to established industry practices to achieve the necessary quality of workmanship.

Introduction
In a paper for the 2009 ECEEE Summer Study, Fawcett and Boardman (2009) summarise the potential of a market transformation approach, but recognise that lessons from appliance markets may not transfer easily to housing: 'the key will be to develop a sophisticated understanding of the housing market; the major actors, their relationships, opportunities for influence, financial flows, the ability of the building industry to deliver efficient new homes and high quality renovations, and a host of other factors which determine how the housing market (or markets) actually works and how efficiency can be made a more central part of market decisions.' (Fawcett, Boardman 2009, p. 227)

Hinnells and Boardman (2008) identify innovation as one key element in a process of market transformation, including innovation of technologies, processes and services: 'it is key, therefore, that we understand how to drive innovation, and that this understanding is common to many actors, including policy makers and decision makers within firms' (Hinnells, Boardman 2008, p. 203)

Between them, these two papers frame a strategic work-plan for investigating the potential for market mechanisms to deliver low-carbon housing. Both of these papers use evidence of past successes in appliance markets to suggest the kinds of policies which might be appropriate, but neither of them actually explores the markets, actor-networks, institutions or innovations which might bring about the changes they describe. This paper attempts to fill in at least some of the detail.

Overview of Market Transformation approaches in appliance markets

Before considering the different context of housing refurbishment, it is worth briefly summarising the pedigree of MT in appliance markets. MT is an approach to policy-making and programme design, which aims to improve the energy performance of whole stocks of energy-consuming products in a market economy (Geller, Nadel 1994). Some of the common themes of the MT approach are the provision of information to help consumers make informed choices at point of sale; rewards and incentives for innovation at the best-performing end of the market; and mandatory minimum standards of performance (Hinnells and Boardman 2008).

The detail of individual programmes to improve the stocks of different appliances takes account of the technical design of the appliance and the condition of the market for it before MT interventions. Thus a programme to transform the stock of fridges will be different in several ways from a programme to improve the efficiency of light bulbs (Geller, Nadel 1994, Boardman et al. 1997, Palmer, Boardman 1998). Background research and stakeholder engagement for the market in question are important early steps in the process (International Energy Agency 2003, p. 30). In mixed market economies, MT is widely seen as a robust and successful approach to policy-making, partly through addressing market failures (in the classical economic analysis) and partly through close working with manufacturers to identify and incentivise technical innovation (eg Hinnells, Boardman 2008, International Energy Agency 2003).

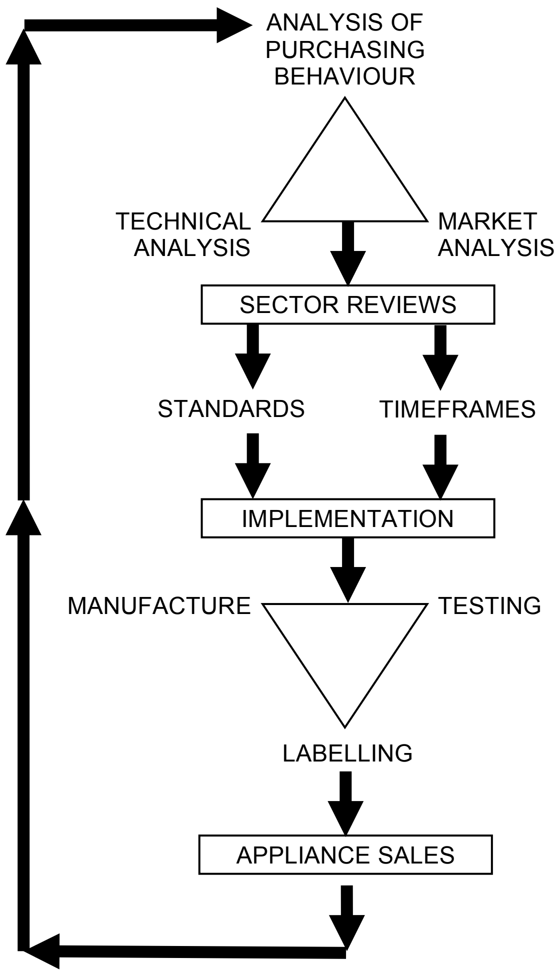

Figure 1. MT system for developing and delivering energy efficiency standards in appliance markets.

Nowadays, MT is a well-established approach in European appliance markets, but it is worth re-visiting some of the complexity and uncertainty that was found in the early days of appliance programmes, as there are many relevant insights for the current situation with housing refurbishment.

When labelling was first introduced for cold appliances (fridges, freezers and fridge-freezers) in 1995, a mandatory minimum standard was scheduled for 1999. The minimum standard was designed to achieve a 15 % improvement in efficiency compared to the appliance average of 1992, although a technical study for the European Union had identified a potential for improving efficiency by 56 % with existing technology (and up to 83 % with technical innovation, such as vacuum insulation). A commitment to revise the standards periodically was also made, underlining the strategy of industry engagement and continual improvement over time, which is now well established (Boardman et al. 1997).

There were many sources of uncertainty over what the real effect of the label might be. Poor installation (eg in fitted kitchens without adequate ventilation to dissipate heat, or placed next to a cooker) had been shown to increase energy consumption by up to 160 %, while the popular 'frost-free' feature on fridges could add up to 45 % (Boardman et al. 1997). Manufacturers and consumers both thought at the outset that more efficient appliances would be more expensive, although there was in fact no observed correlation in the end, because of non-energy-related improved efficiency of production processes, strong price competition in the mid-range products keeping margins low, and features such as curved 'American' styling commanding premium prices (Boardman et al. 1997).

There were similar concerns about the number of old appliances remaining in the stock through the second-hand market, and about how intelligible the label was for those with low levels of literacy and numeracy. Retail staff were found to be highly influential in the purchasing decision process, and their own motivations were in some cases not related to the energy efficiency of the appliance, but to do with other commercial incentives, notably the commission earned from selling extended warranties. Retailer companies also exercised influence by their choice of which products to stock and which to actively promote (Boardman et al. 1997).

The MT process is based on research of different kinds: exploring the technical potential for improvement in energy efficiency; an analysis of the market for the appliance group in question; and research on consumers' purchasing behaviour and the dynamics of decision-making. Minimum energy performance standards (including future standards) are developed in the light of this research, which also has a bearing on the timescale over which change is expected to take place, typically based on analysis of appliance replacement cycles. The setting of standards can include activities such as competitions (where voluntary standards are set to challenge innovation among the best-performing models), as well as negotiations between stakeholders on the setting of mandatory standards.

Manufacturers then produce new appliance designs, which undergo testing before moving on to full-scale production.

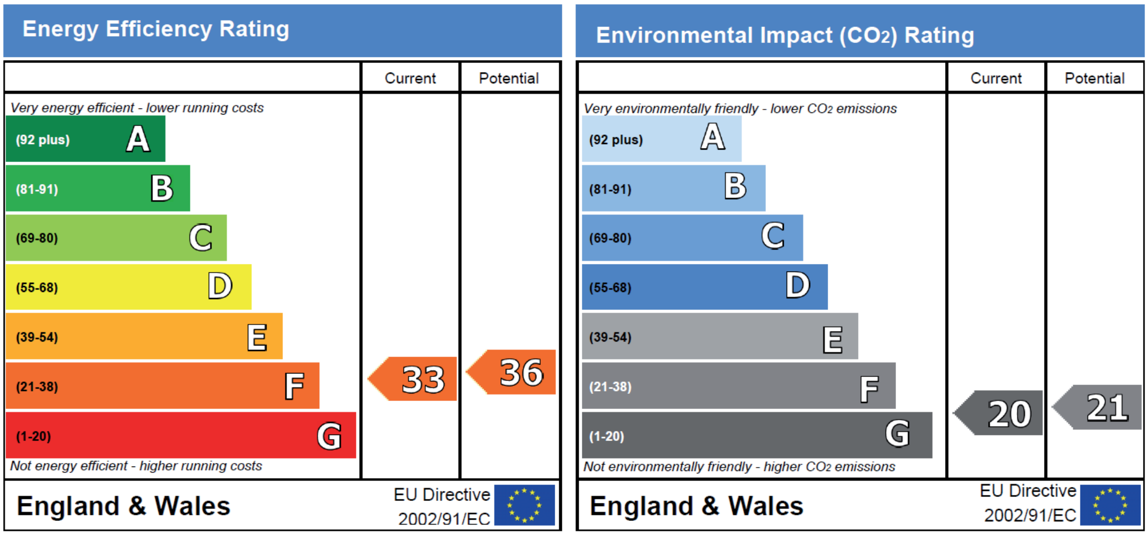

Figure 2. Energy label (energy performance certificate) for housing in England & Wales.

With appliances, the responsibility for producing the energy label also resides with the manufacturer (although the retailer has a role in ensuring that it is displayed). By involving industry and policy stakeholders in an open process of consultation and decision-making, it has been possible to improve the energy efficiency of products available for purchase and to keep up the momentum for continued improvement at a pace which is achievable. The whole process is iterative, with new rounds of activity being informed by the results of previous rounds (Figure 1).

Housing and energy performance – a system of markets

The Energy Performance Certificate (EPC) is the UK's energy label for housing, fulfilling one of the requirements of the transposition of the Energy Performance of Buildings Directive (EPBD): it has been required for all property sales and rentals since 2008, and its principal innovation compared with appliance labels is the dual rating 'current' and 'potential', in recognition of the fact that improvements to energy performance are not achieved through product replacement, but through the provision of a refurbishment service (Figure 2).

The EPC creates a link for the first time between two separate markets – the market for property transactions (sales and rentals) and the market for refurbishment, which includes installations of energy efficiency measures, installations of microgeneration technology and a general set of services classed as repair, maintenance and improvement (RMI). The whole can be thought of as a system of markets arranged hierarchically (Figure 3[1]). The role of the EPC in creating this information-link between property and refurbishment is clearly important, but a study of over 300,000 EPCs showed that the mean uplift between 'current' and 'potential' on the UK's EPC is 10 SAP points, while the mode is 3 SAP points (National Energy Foundation 2009). In most cases this means that the energy rating (A – G scale) for 'potential' is the same as for 'current' or is only one band higher. The assessment of 'potential' is based on measures supported by existing policies (providing grants, advice services and limited installer accreditation), but it does not reflect either the technical achievements of best practice or the long-term reductions required to meet the UK's climate change targets (Killip 2008b).

The market for RMI dominates the other two sub-sectors of the refurbishment market, with £28,000 million (33,250 million Euros) spent on home maintenance and repair in 2008 (Office for National Statistics 2009), compared with approximately £800 million (950 million Euros) on energy efficiency under the energy supplier obligation (CERT). More research is needed to identify how much of the RMI market represents genuine potential for integrating low- carbon works, but the evidence of pioneers is that there are many good opportunities at the level of room-by-room projects, such as new kitchens, bathrooms, conversions and extensions (Sustainable Energy Academy). Cost and disruption can both be substantially reduced by being made marginal.

What is low-carbon housing refurbishment?

Several publications since 2003 have used computer models and scenarios to quantify the scale of the challenge and assess the technical potential for emissions reductions. These include several studies of the housing sector in isolation (eg Johnston 2003, Boardman et al. 2005, Centre for Sustainable Energy et al. 2008) and other studies focused on the UK-wide energy system (Skea et al. 2009). All of these studies broadly agree that the technical potential for improved efficiency in the residential sector is very large, using currently available and 'near market-ready' technology. This is not to say that improved technology would not be beneficial, but the fact that simulations can achieve these results without assuming major technical innovations shows that the challenge is primarily about technology deployment, rather than a lack of suitable products and materials. The figures used in these models are based on system components (eg elemental U values), and the fact that

1. A branch with no 'daughter' label indicates that the 'mother' has an incomplete set of market activities in the diagram. Associated markets for domestic energy assessments (providing EPCs) and installer training are not shown, in the interests of clarity.

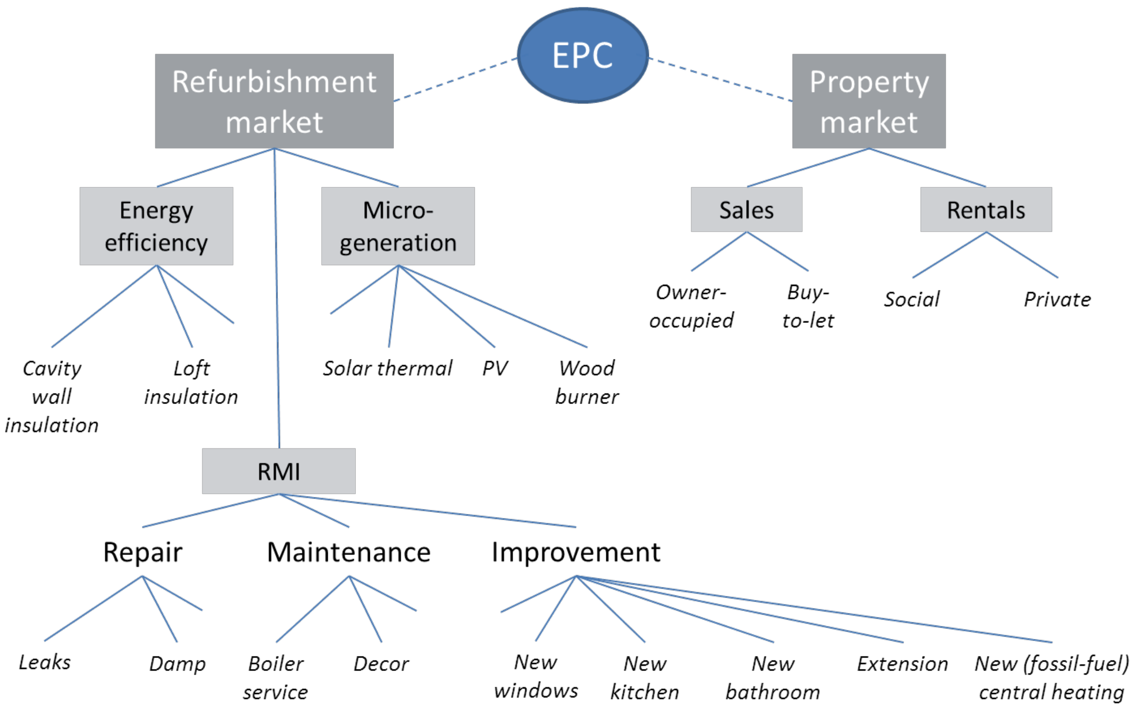

Figure 3. A simplified system of markets for low-carbon housing refurbishment.

they do not allow any explicit margin for error in installation means, effectively, that the quality of installation is assumed to be perfect.

There is not space in this paper to describe all the technical issues associated with low-carbon refurbishment, but the experience of pioneers is that it requires a well thought-through combination of products, systems, and quality of workmanship. A brief summary of one rather less successful refurbishment project will serve to illustrate how things can go badly wrong. This case study was the conversion of a 1930s farm building into offices, but the principles demonstrated here are also relevant to domestic projects. For this refurbishment the wall insulation system featured a number of regularly placed metal rails for fixing the insulation to the wall, which resulted in significant repeating linear thermal bridges (metals being good conductors of heat). The insulation on this project was also very loosely fitted, with numerous visible gaps and holes inaccurately filled with small off-cuts of insulation material (Figure 4).

Once the wall had been finished with a layer of plasterboard, these details were hidden from view. In this case the temperature gradient and the repeat thermal bridging from the metal fixing rails were diagnosed with thermal imaging (Figure 5).

The design engineer for this project reported that the insulation was effectively being bypassed with warm air being carried around the insulation by convection, resulting in the bottom of the wall being cooler than the top. Such 'convection loops' are attested elsewhere, and are of particular significance in wall constructions, where the vertical alignment of the insulation increases the chance of convection arising (Trethowen 1991). The gas consumption for heating on this project was approximately double the predicted amount (Watts 2004). The monitoring and reporting of this project was unusually thorough, but there have been other instances of poor workmanship resulting in compromised performance (Olivier 2001).

Heating controls (and their use by residents) take on a more significant role as the energy supply technologies become more numerous and the overall system becomes more complex. A solar water heater will typically require some form of back-up system, especially in winter, but the extent to which the solar system actually contributes to the overall energy budget can vary considerably. In a review of 55 solar hot water systems, it was found that on average the solar panel provided 15 % of household hot water demand, compared with the installers' and manufacturers' claim that these systems provide 60 % (Hill 2008).

The problem is primarily one of timing: if a gas-fired boiler is programmed to ensure that there is a full tank of hot water in the morning, there may be little or no need for the energy from a solar panel during the day, meaning that over 90 % of the potential benefit of the solar system is lost (Hill, Lynch & Levermore 2010). The requirement to raise stored water temperatures to 60 °C for an hour to prevent incubation of Legionella bacteria is also estimated to reduce the effective savings from solar hot water by 25 %, with some evidence to suggest that a lower temperature (eg 50 °C) would be appropriate in domestic systems (Hill, Lynch & Levermore 2010).The difference between potential and achieved performance may vary to a large degree because of poor integration of technology, controls, user awareness and user behaviour. Although some solar system installers are aware of these issues and treat system integration (including controls set-up and client training) as a part of their work, there are many others who clearly do not. One contractor reported raising the issue of solar optimisation with a well-known manufacturer of heating system controls, to which the response came back that the problem is well-known but there are no plans to attempt to remedy it (Kaushal 2008).

Figure 4. Internal wall insulation (expanded polystyrene) before plasterboard is fitted, showing metal fixing rails and gaps in the insulation due to poor workmanship.

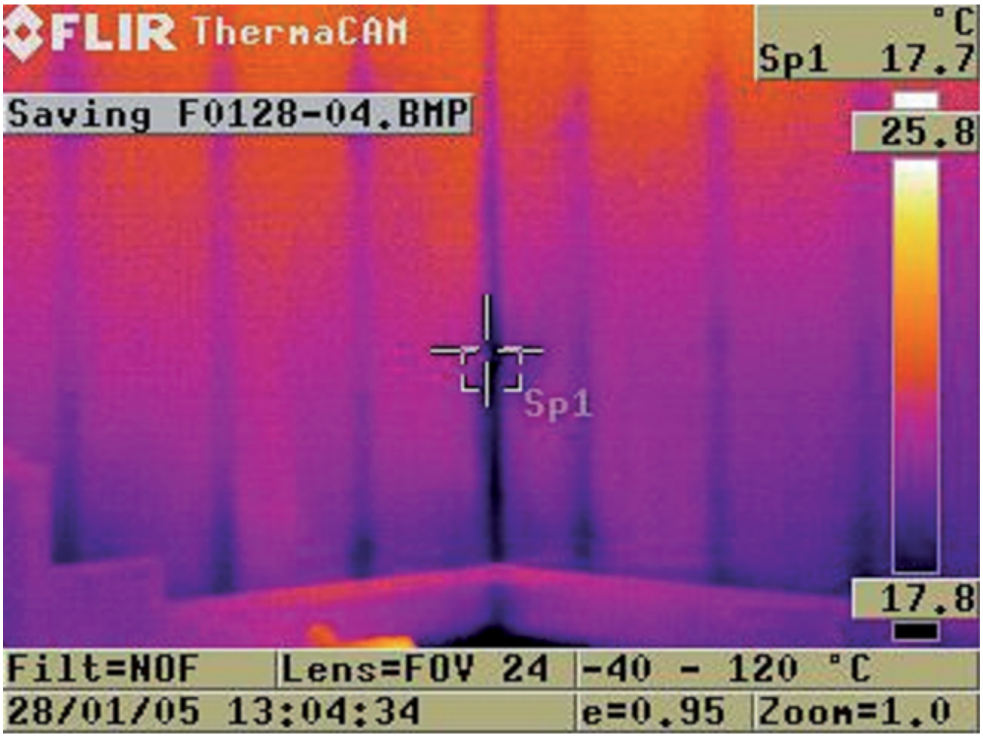

Figure 5 Thermal image of a completed wall in the same project as Figure 4, showing repeating thermal bridges due to metal fixing rails and a temperature gradient across the wall height due to convection currents flowing around the poorly fitted insulation.

Costs of low-carbon refurbishment

Three different reports have provided estimated costs for refurbishing the UK's housing stock to some low-carbon standard, but the methods, estimates and target emissions reductions are not consistent across the three (Table 1).

Further estimates have been made on a 'per home' basis in relation to a demonstration project by Retrofit South East (Price 2010) and in the industry stakeholder workshops coordinated by UK Green Building Council in relation to the PAYS finance model (UK Green Building Council 2009). Based on figures from these two reports, plus inferred unit costs for each of the three reports summarised in Table 1, achieving the 80 % reduction target will cost between £5,000 and £40,000 per dwelling, each of these studies having estimated their costs in a range from low to high. Among these five studies the mean low cost estimate per dwelling is £12,400 and the mean high cost

Table 1. Published cost estimates for low-carbon housing refurbishment in the UK.

Report	Cost estimate (£bn/year)	Target outcome	Methodology	Comments
'Home Truths' (Boardman 2007)	9.9 – 12.9	-80% CO_2 by 2050	Sum of estimates for proposed investment programmes and tax reform	£12.9bn from 2008; £9.9 – 10.4bn from 2017 to 2050.
'Building a Greener Britain' (Killip 2008a)	3.5 – 6.5	-60 – 65% CO_2 by 2050	Extrapolation of marginal costs from 2 recent case studies	Marginal costs for low-carbon work were 13 – 15% of total costs
'How low?' (CSE et al 2008)	2.6 – 3.5	-80% CO_2 by 2050	Model of installation rates, technology unit costs, discount rates. Lower estimate includes technology learning for LZCs.	Excludes cost of assumed 60% reduction in carbon intensity of grid electricity by 2050

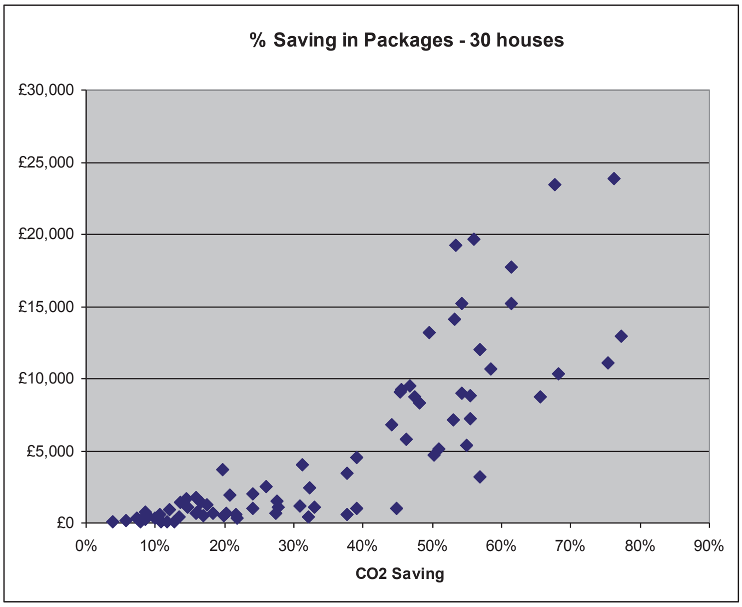

Figure 6. Scatter graph of estimates for marginal cost of low-carbon refurbishment against CO_2 emissions reduction for 30 houses. (Source: Smith 2010)

estimate is £23,100, but data points are widely scattered with no clear line of best fit. This can be accounted for by the differences in the assumptions between these studies, which include: whether costs are full or marginal; whether (and how much) money is required for institutional infrastructure; whether costs are included for an assumed decarbonisation of electricity. There are too many dependent variables involved here, and the methodologies employed are too different to make detailed comparisons meaningful. However, all of these estimates are at least of the same order of magnitude.

A more consistent set of cost estimates has been calculated by Parity Projects, using the company's own software to estimate the marginal cost and percentage CO_2 emissions reduction for different dwellings using, in each case, 12 months consumption from fuel bills as a baseline (Smith 2010). The scatter of data points achieved follows the sort of curve that might be expected, with a steeper increase in cost as the emissions reductions get higher (Figure 6).

In fact, at the level of an 80 % reduction, the figures in Figure 6 are quite close to the mean figures from the published reports discussed above and summarised in Table 1, suggesting that £12,000 - £25,000 per dwelling is the best available estimate of costs for achieving an 80 % emissions reduction. It should be emphasised, though, that the basis for comparing the figures from these different sources is very uncertain. Where the Parity Projects figures are based on marginal costs (ie they assume that low-carbon works are only realistically carried out when other works are already planned), they do not include costs for administrative support systems that might be needed, should the approach be rolled out on a national scale. In contrast, Boardman (2007) does include some costs for such administrative infrastructure, which goes a long way to explaining why her total estimates are among the highest reviewed here.

Understanding conservatism and innovation in construction

One of the key tenets of MT approaches in appliance markets is to foster innovation through a number of policy initiatives, such as the Energy + competitions, which are designed to accelerate improvements in technical performance.

The construction industry is widely viewed as conservative and resistant to innovation (e.g. Egan 1998). However, that conservatism can be explained in the context of custom and practice in the industry, where there is a self-reinforcing tendency to use familiar products and familiar techniques: the most widely-used products are widely available, and there are advantages to be had in using a range of products which are all compatible with each other, of known quality and price, and for which there are few customer complaints after installation (Killip 2008a). This has led to the proposal that products and practices need to meet eight distinct criteria if they are to be seen by the industry as being part of 'buildable' solutions (source: Killip 2008a):

- **Practical** – solutions need to be relatively simple and quick to implement
- **Replicable** – a refurbishment package needs to be something that can be installed many times over by the general population of installers, rather than being the preserve of some kind of elite
- **Affordable** – unit costs may well come down over time and can be influenced by policy, but there is no point in promoting items at any given time which are out of reach of a viable market
- **Reliable** – products and systems need to work well and be robust
- **Sellable** – the costs and benefits to both customer and installer need to be readily understood
- **Available** – specialist products that take weeks to order will not find favour among the mainstream: developing product supply chains is key
- **Guarantee-able** – installers make their reputation on delivering things that work and, conversely, will abandon products or methods which lead to repeated call-backs and complaints
- **Profitable** – firms need to be able to make a living from it

Harris and Halkett (2007) argue that innovation in construction does occur, but that it is 'hidden' from the conventional indicators of R&D spending and patent applications, which policy-makers and industry actors typically use as metrics for innovation. These indicators relate to innovation of new technology, but construction is as much about the process of putting materials together as it is about the materials themselves. Focusing on the new-build sectors within construction (rather than refurbishment), these authors identify three key aspects of innovation in this sector Source: (Harris, Halkett 2007):

- Innovation in construction is highly non-linear: it derives from evolving working practices, project collaborations and problem-solving
- Innovation is driven by regulations, client demand and skills supply
- Innovation takes place between construction companies, consultants and clients, not in the R&D lab

This has far-reaching implications for an approach to developing MT policies for building stocks, as it suggests that policy-makers need to engage with this very different way in which the industry innovates: the emphasis is on project working and experimentation, for which the impetus needs to come from regulation (in the absence of significant levels of client demand). An account of one approach to innovation in this sector will serve to highlight the importance of integrating new products and new processes when it comes to transforming this service-based market.

In 2008 the Technology Strategy Board (TSB)[2] launched a £17 million (20.3 million Euro) competition called 'Retro-fit for the Future' (RFF), which aims to create and monitor advanced low-carbon housing retro-fit projects among low-rise homes in the social housing sector, with a requirement to provide monitoring of technical systems for a minimum of 24 months (Morgan 2009). From a total of about 350 applications, 87 were selected to go ahead in 2010 (Technology Strategy Board 2010).

The maximum amount on offer was £150,000 (179,100 Euros) per property, and the RFF set an ambitious emissions target of 20 kg CO_2/m^2.year (as modelled with PHPP software[3]), which is broadly consistent with the 80 % emissions reduction target (Morgan 2009). The competition's aim was to stimulate innovative approaches to the 80 % reduction target, rather than investigating cost-effectiveness (Morgan 2009).

In the end, each of the 87 funded projects was set to receive an average of £142,000 (169,500 euros) (Technology Strategy Board 2010), which is well in excess of the £5,000–40,000 (6,000–47,800 euro) range found in published reports (summarised above). This is therefore a large amount to spend per property, even taking account of the monitoring requirements, and it has allowed applicants to focus on innovative technical solutions, as shown by a review of 20 randomly-selected applicants (not necessarily successful) to the RFF competition (Table 2).

Some innovative insulation materials were proposed, including aerogel phase-changing materials, vacuum insulation panels (including nanopore technology with tiny vacuum cells). One project proposed to remove chimneys from the property as a way of achieving airtightness and removing the risk of condensation damaging brickwork inside the chimneys. Two out of 20 projects proposed removing the outer leaf of a cavity wall, in order to create extra width for wall insulation, even though this created new structural problems, which had also to be addressed (a cavity wall's strength derives partly from two adjacent leaves being tied together, so removing one leaf weakens the structure). One team had used thermal imaging to identify gaps in existing cavity wall insulation, which it was then proposed to remedy. Other innovations included: provision of a PV-charged battery and dedicated DC lighting circuit to avoid energy losses in transforming DC current to AC; insulated decorative cornices to reduce thermal bridging at wall-ceiling junctions; waste hot water heat recovery systems in two projects; use of carbon ties and special joist-hangers to reduce condensation risks associated with internal wall insulation, particularly where metal fixings are effectively encased in insulation material at wall-floor junctions. Not all of these innova-

2. The Technology Strategy Board (TSB) is a quasi-autonomous public body, sponsored and funded by the Department for Business, Innovation and Skills, which 'operates at arm's length [from government] as a business-led executive non-departmental public body'.

3. Or 17 kg CO_2/m^2.year modelled with SAP.

Table 2. Summary of technical proposals found in 20 round-two applications to TSB Retro-fit for the Future competition (based on data from *(Morgan 2009).*

Thermal fabric	Qty	Ventilation	Qty	Space & water heating	Qty
Floor insulation	20	MVHR	15	Solar water heater	11
Wall insulation	20	Passive ventilation	1	Heat pumps	9
Roof insulation	20			Gas boiler	6
				Micro CHP	4
				Wood stove/boiler	2
Lights & appliances	**Qty**	**System controls**	**Qty**	**Micro-generation**	**Qty**
'Low energy' lights	7	'Smart' controller	7	Photovoltaics	11
A+(+) appliances	6			Micro CHP	4
LED lights	5				
Voltage regulation	3				

tions would necessarily work as expected, but the TSB's aim to foster innovation is reflected in this list of unconventional approaches and uses of technology.

In addition to the projects funded through the TSB RFF competition, there are dozens of (mainly privately owned) homes which have undergone low-carbon refurbishment, generally to a less ambitious standard than the TSB RFF projects, but also costing considerably less (Sustainable Energy Academy).

Non-compliance with standards

Compliance with energy standards has been investigated more for new-build homes than refurbishment, given the longer history of regulation of new homes. In the UK an airtightness standard of $10m^3/hr/m^2$ @ 50 Pascals has been a requirement for new housing since 2002 (which is relatively leaky compared with the Passive House standard of $0.6\ m^3/hr/m^2$ @ 50 Pascals). Compliance levels were initially about 50% (Grigg 2004) and the industry has continued to find this new requirement challenging. Where developments have failed to meet the airtightness standard, remediation has proved to be extremely difficult because the details which need to be re-worked are encased within the structure of the building and it may be practically impossible to put the faults right without demolition of parts of the structure, which is prohibitively expensive and time-consuming. A new and unsuspected source of ventilation heat loss was discovered in a new housing development in 2007, due to air flowing through uninsulated cavity walls between adjoining houses (Lowe et al. 2007). This was only discovered and publicised because of the strong commitment on this project to detailed monitoring and reporting. Getting these details right is not simply a technical challenge: it is incompatible with the traditionally fragmented roles on construction sites, in which no single person takes responsibility for the energy performance of the end-product. The challenge of low-carbon led the developer on this particular project to conclude that 'the industry needs to re-think the whole design and construction process by adopting an integrated systems approach, all of which must be underpinned by a culture of continuous improvement (National Trust et al. 2008, p. 4).

The distance that the mainstream still has to travel is demonstrated by one small building firm, which has managed to achieve airtightness of $0.25\ m^3/hr/m^2$ @ 50 Pascals – forty times better than the UK standard, and more than twice as good as Passive House. The firm's director invested in airtightness testing equipment and took the time to test partially completed buildings, highlighting the details where the leaks occurred and learning, through a process of trial and error, how to avoid such leaks in the future. When questioned about why this one firm was able to achieve what the rest of the industry struggles with, this practitioner commented: '*If you can't have an influence on all the factors, you kind of know the project isn't going to work.*' When questioned further about what was meant by 'an influence on all the factors', the response was a clear need for what he called *'a tsarist role'*. This role is effectively absent in mainstream construction projects, which led him to a down-beat appraisal for the industry as a whole: *'it's a long way before it's mainstream, a long way.'* The issue here is not so much technical as contractual and relationship-based, with poor energy performance inextricably linked to the fragmentation of roles and the adversarial approach to risk management in conventional practice:

> [Y]ou start work on a project … all the M&E[4], the consultants, the architects, everyone there … […] no-one really grasps it and says "this is the methodology." So, everyone kind of wants to take their fee but wants to mitigate risk. […] But … the project's gone to the dogs[5] straight away because no-one's committed to it.

This characterisation of the construction process as antagonistic, adversarial and unfocused on final outcomes is very similar to the conclusions of two seminal reports, 'Re-thinking Construction' and 'Accelerating Change', which found that the construction industry is risk-averse, with individual firms seeking to limit their own liabilities on projects, rather than work collaboratively with others to achieve a well-integrated design and good attention to detail in the construction process (Egan 1998, Egan 2002).

4. M&E = mechanical and electrical, i.e. building energy services.

5. British idiomatic expression: If something has gone to the dogs, it has gone so badly wrong that it cannot be retrieved or redeemed.

Training for low-carbon refurbishment services

Vocational training in England[6] is managed by Sector Skills Councils (SSCs), which were introduced in 2002 to give employers a strong voice in the development of a skills agenda for their industries. The 25 SSCs cover about 85 % of the UK economy, with coverage for the remaining 15 % being provided by the Alliance of Sector Skills Councils (ASSC). The ASSC is also the strategic body for all SSCs, acting as an umbrella organisation and coordinating communication with government on strategic skills issues. The UK Commission for Employment and Skills oversees the performance of the SSCs, advising the government on their relicensing.

Each SSC is responsible for setting the National Occupational Standards (NOS) in the relevant economic sector. The NOS documents are key to the development or refinement of vocational training programmes, as it is the NOS which describe what a competent person in a given occupation should be able to do. Amendments to the NOS will feed through to the requirements for different National Vocational Qualifications (NVQs). A different tier of organisations – the Awarding Bodies – take the NVQ requirements and turn them into specific curricula, which are then delivered in colleges up and down the country. NVQs are graded according to the level of skills required: most NVQs in construction are level 2, while most of the NVQs for bolt-on technologies such as solar panels are level 3. Project management and other supervisory functions may reach level 4 and occasionally level 5.

The SSC framework, with its employer-led structure and focus, means that only those skills which respond to a market need will be developed. If industry is to invest to make it work, then there has to be sufficient conviction that this is a real market, i.e. that the investment in skills development will lead to some economic benefit to industry members. This hinges crucially on the industry leaders' perception of whether there is a market for the new low-carbon skills, and that is intimately linked to government policy.

Some courses on sustainability issues (including low-carbon) have been introduced by colleges on a speculative basis but they have invariably been withdrawn due to a lack of students (Bolton 2009). The market for training is dependent on the market for jobs and, while a college may choose to try out a new course, it can only be maintained if there is ongoing interest from trainees. The Innovation and Growth Team set up by the Secretary of State for Business, Innovation and Skills identified one of the principal barriers to progress towards a low carbon future as 'the lack of drivers for a change in customer demand, without which the supply side lacks the confidence to invest in new products and services for which there may be no market at a profitable price' (Department for Business, Innovation and Skills 2010). A strategy document sponsored jointly by industry and government in 2008 made essentially the same point: 'unless demand is nurtured, training products and services will not be used, and the knowledge/skills base will not be developed' (Department for Business Enterprise and Regulatory Reform 2008, p.23).

6. Vocational training is a devolved issue in the UK: only the English system is described in detail here.

Low-carbon refurbishment as business opportunity and job creation

The task of achieving good energy performance through housing refurbishment is clearly challenging for the construction industry, but the scale of the economic opportunity is not lost on them. Although the cost estimates for the work are not clear, a programme to refurbish 500,000 homes per year for 40 years would cost several billion euros (Killip 2008a). The rewards for the industry are very large, while the social benefits in terms of health and well-being are also well understood. From a wider economic perspective, refurbishment of housing has been identified as one of the best means to create long-term, sustainable jobs in any sector of the entire economy (Bowen et al. 2009). Nonetheless, achieving the necessary integration of energy systems and quality of workmanship across the entire housing stock is a huge challenge, with the very real risk that the work carried out does not in fact meet the necessary standard. In this case, the money will have been largely wasted and the benefits will turn out to be illusory.

Towards a model of Market Transformation for housing refurbishment

While labels are the most visible tools in the MT toolkit, it is the combination of different tools in different contexts which provides the impact in the market (Boardman et al. 1995). Thus, a label may be a suitable and sufficient policy where there is a large range of efficiencies and where consumer awareness is already high. A financial incentive in addition to a label may be appropriate where consumers do not pay attention to energy at the point of sale. Procurement is appropriate when the technical potential is much greater than anything on the current market. Voluntary agreements may be better than regulation where technology is not stable but changing fast. Standards are more appropriate where technology is stable (Boardman et al. 1995). If this logic is applied to UK housing refurbishment, a successful combination would include labels, incentives, procurement and standards.

As discussed above, the labelling system (EPC) hugely under-states the potential for improvement and is in need of reform. Financial incentives can be put into two broad categories: provision of capital (to pay for the work) and sweeteners (to encourage pro-environmental behaviours). Various incentives of both types can be envisaged, including: provision of loans through existing financial institutions; the proposed new charge on property under the Green Deal; tax rebates on Council Tax (a property-based tax which supports local public services); varied rates of Stamp Duty (property purchase tax), and wider fiscal reforms, such as changes to the VAT regime (Killip 2008a).

While EPC reform and financial incentives are not straightforward policies to get right, the larger challenge for developing an MT approach for housing refurbishment is in the use of procurement and the setting of standards. In order to manage the risks of fragmentation, un-integrated solutions, poor compliance, and ignorant, unaccountable builders undermining the aim of achieving a low-carbon housing stock, a supreme effort of coordination is needed.

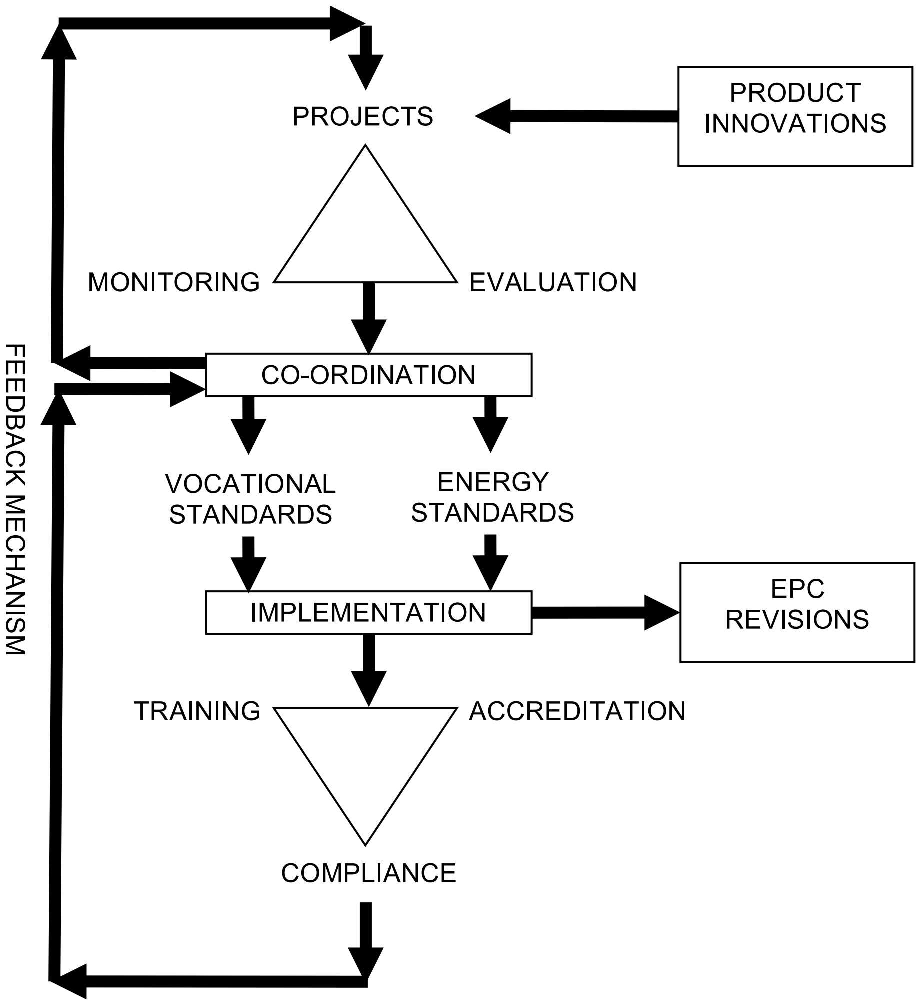

Figure 7 Proposed model for coordinating the iterative development of standards in parallel with relevant techniques and practices: feedback on problems at the compliance stage inform new innovations.

A model for continuous improvement through industry engagement is proposed in Figure 7, which is a development of the MT system for appliances, described in Figure 1. Figure 7 shows energy standards being developed in parallel with the necessary vocational standards, all based on evidence from well monitored innovative projects, which would need to be defined, funded and coordinated.

A co-ordination role is required to distil the lessons learned from the monitoring of projects and to manage the various tensions inherent in the process. A judgement is needed for each iteration of the process to decide which energy standards to aim for and how the vocational standards need to evolve if that the work is to be done sufficiently well.

This process of standard-setting will need to strike a balance between stretching practitioners to adopt unfamiliar products and techniques, while also maintaining wide industry support for the overall process. The standards thus set will then need to be implemented through existing institutional structures, so that each element reinforces the others: providing information through the EPC which reflects best practice in the industry; delivering training courses for contractors (including site supervisors playing an important integration role) to equip them to carry out the refurbishment work needed to meet the standards in force; providing the basis for accreditation and compliance-checking regimes, which focus on the energy standards which the contractors are being trained to achieve. The content of training courses, minimum standards, and compliance regime need to be complementary: each needs to reinforce the same important messages about quality of workmanship, quality of design, and system integration.

The standards developed by this process would aim to combine the requirements of the over-arching climate change target by 2050, but would do so in such a way that there would be an ongoing process of learning, coordination and improvement. Thus, the early iterations of the process might not deliver homes to a high enough standard, but these early projects would inform the development of the next phase. The standards developed by this process would also need to inform other parts of the overall system, including the modelling behind the EPC and the training of the domestic energy assessors, whose job it is to produce the EPCs.

All professionals involved in the property and home refurbishment markets would need to work within a new regime of regularly revised mandatory standards, much like the new-build industry works with various approved documents to meet the building regulations. Initial research suggests that a technical standard lends itself best to a 'whole home' approach in which all works are managed in one continuous project; but the market operates much more on a 'room by room' basis. Pioneers have successfully integrated room by room approaches over several years, but the need to produce an integrated result with different contractors working at different times on the same building is an additional coordination task for industry that finds coordination particularly difficult. These are real tensions that will need to be managed and resolved.

Mobilising the interest and cooperation of the various actors in this diffuse actor-network is a challenge in itself, and one which hinges on the perception among industry members of the future size of the market. Voluntary schemes, demonstrations and pilots can all inform the process, but they do little to stimulate the mass market. Regulation through a mandatory energy performance standard (MEPS), announced several years in advance in order to give industry time to invest in supply chains and training, is a key part of the process of industry engagement. In order for that MEPS to be delivered on the ground, it needs to be matched by a vocational standard. These standards will not achieve market transformation on their own, of course, but nor do the other policy tools achieve it without this dual set of minimum standards being in place.

Monitoring, evaluation and dissemination need to underpin the entire process, so that the lessons from one round of innovation are fed all the way through to the compliance regime; and the lessons from that round of compliance testing feed back into the next round of innovation. A central coordinating body is needed because there are multiple sources of information in the system of markets that make up the current delivery mechanism for refurbishment. The EPC, the building industry, product manufacturers, estate agents, finance brokers and compliance checkers all need to be working to the same set of standards in order to minimise the risk of the whole exercise unravelling. Multiple sources of advice and information could easily lead to confusion, mis-information, inaction or widespread specification of refurbishment works that do not meet the policy objectives.

To meet the low-carbon agenda, there is a need for some independent monitoring to be done, with the results being taken into account in the process of finding buildable solutions. There is risk involved in setting a standard which the contractors think is un-buildable, but it is clearly counter-productive to adopt a 'solution' that has the support of the contractors but fails to meet the policy goals. A process of negotiation is needed, involving contractors in experimental projects, backed up by rigorous monitoring and evaluation. Coordination of learning is key. There is a need for a body which can do this work and it needs to be independent, authoritative and evidence-based. This body could manage an ongoing programme of innovative projects, where suitable properties would be bought, and different approaches to low-carbon refurbishment conducted as field trials, with monitoring and evaluation of the results. Each property, once the trials were complete, could be re-sold to help finance the next round of projects. In order to test different variables in reasonable-sized samples, the aim might be to carry out 500 – 1,000 such projects in the first three years, after which time the need for further work would be reviewed. The geographic spread of projects would need to match the local/regional nature of RMI markets, variations in regional economies and differences in housing stock types and climate.

The institutional framework to manage such a programme does not currently exist, although different aspects of the knowledge and expertise required can almost certainly be found in different places. The challenge for government and its institutions is to bring disparate capabilities together, combining several key roles: coordination and engagement of multiple groups of stakeholders; development of energy standards based on field trials and technical studies; simultaneous development of occupational standards in collaboration with Sector Skills Councils and bodies representing the vocational training system; liaison with manufacturers and wholesalers of products, including product innovators; coordination of the energy standards with the detailed workings of the EPC; better understanding of how occupants behave in real-life in refurbished homes, and the impact that has on energy consumption and CO_2 emissions.

References

Boardman, B. 2007, *Home truths: a low-carbon strategy to reduce UK housing emissions by 80% by 2050*, Environmental Change Institute, University of Oxford.

Boardman, B., Darby, S., Killip, G., Hinnells, M., Jardine, C.N., Palmer, J. & Sinden, G. 2005, *40% House*, Environmental Change Institute, Oxford.

Boardman, B., Lane, K., Hinnells, M., Banks, N., Milne, G., Goodwin, A. & Fawcett, T. 1997, *Transforming the UK Cold Market*, University of Oxford, Oxford.

Bolton, M. 2009, Pers. Comm. *The work of construction colleges in promoting skills for sustainability*.

Bowen, A., Fankhauser, S., Stern, N. & Zenghelis, D. 2009, *An outline of the case for a 'green' stimulus*, London School of Economics, London.

Centre for Sustainable Energy, Association for the Conservation of Energy & Moore, R. 2008, *How low: achieving optimal carbon savings from the UK's existing housing stock*, WWF.

Department for Business Enterprise and Regulatory Reform 2008, *Strategy for sustainable construction*.

Department for Business, Innovation and Skills 2010, *Low Carbon construction Innovation & Growth Team: Emerging Findings*, H M Government.

Egan, J. 2002, *Accelerating change*, Strategic Forum for Construction, London.

Egan, J. 1998, *Rethinking construction*, Department of Trade and Industry, London.

Fawcett, T. & Boardman, B. 2009, "Housing market transformation", *European Council for an Energy Efficient Economy Summer Study* eceee, pp. 225.

Geller, H. & Nadel, S. 1994, "Market Transformation Strategies to Promote End-Use Efficiency", *Annual Review of Energy and the Environment,* vol. 19, pp. 301-346.

Grigg, P. 2004, *Assessment of energy efficiency impact of Building Regulations compliance*, BRE, Garston.

Harris, M. & Halkett, R. 2007, *Hidden innovation: how innovation happens in six 'low innovation' sectors*, National Endowment for Science, Technology and the Arts, London.

Hill, F. 2008, *Consumer Impacts on Dividends from Solar Water Heating*, MSc edn, University of East London.

Hill, F., Lynch, H. & Levermore, G. 2010, "Consumer impacts on dividends from solar water heating", *Energy Efficiency,* [Online], , pp. 30 June 2010. Available from: http://www.springerlink.com/content/p0086t6447812111/fulltext.pdf.

Hinnells, M. & Boardman, B. 2008, "Market transformation: innovation theory and practice" in *Innovation for a Low Carbon Economy - economic, institutional and management approaches*, eds. T. Foxon, J. Köhler & C. Oughton, Edward Elgar, , pp. 203-229.

International Energy Agency 2003, *Cool appliances: policy strategies for energy-efficient homes,* IEA/OECD, Paris.

Johnston, D. 2003, A physically-based energy and carbon dioxide emission model of the UK housing stock, Doctoral thesis, Leeds Metropolitan University.

Kaushal, J. 2008, Pers. Comm. *Report of conversation with a heating system controls manufacturer about the prioritisation of fossil fuel over solar energy in providing domestic hot water*.

Killip, G. 2008a, *Building a Greener Britain*, Federation of Master Builders, London.

Killip, G. 2008b, "It's the size of the reduction target, stupid! The need for a wholesale re-think of energy efficiency policy in UK housing", *ACEEE Summer Study on Energy Efficiencyin Buildings*American Council for an Energy Efficient Economy, .

Lowe, R., Wingfield, J., Bell, M. & Bell, J.M. 2007, "Evidence for significant heat losses through party wall cavities in load-bearing masonry construction", *Building Services Engineering Research and Technology,* vol. 28, no. 2, pp. 161-181.

Morgan, N. 2009, *TSB Retrofit for the Future competition phase 2 assessor guidelines*.

National Energy Foundation 2009, *Energy performance certificates: seizing the opportunity*, National Energy Foundation.

National Trust, Redrow Homes, Bryant Homes 2008, *Volume - learning the lessons from Stamford Brook*, The National Trust

Office for National Statistics 2009, *Construction Statistics Annual*, Office of Public Sector Information.

Olivier, D. 2001, *Building in ignorance. Demolishing complacency: improving the energy performance of 21st century homes*, ACE/EASSOX.

Palmer, J. & Boardman, B. 1998, *DELight*, Environmental Change Unit, Oxford.

Price, D. 2010, *Financing low carbon refurbishment*, Presentation

Skea, J., Ekins, P., Winskel, M., Howard, D., Eyre, N. & Hawkes, A. 2009, *Making the transition to a secure and low-carbon energy system: synthesis report*, UK Energy Research Centre.

Sustainable Energy Academy *, Old Home Super Home*. Available: http://www.sustainable-energyacademy.org.uk/.

Technology Strategy Board 2010, 25 February 2010-last update*, £17m government investment in retrofitting to pave the way for low carbon housing*. Available: http://www.innovateuk.org/content/press-release/17m-government-investment-in-retrofitting-to-pave-.ashx [2010, August 7] .

Trethowen, H.A. 1991, "Sensitivity of Insulated Wall and Ceiling Cavities to Workmanship", *Journal of Building Physics,* vol. 15, no. 2, pp. 172-179.

UK Green Building Council 2009, *Pay As You Save (PAYS) Task Group - final report*.

Watts, B. 2004, *Design versus monitored energy consumption at Beaufort Court*.

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