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Retrofitting Sustainability in the Built Environment

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Foreword

This paper is based on the work of the 'Retrofitting Sustainability' project, October 2011 to June 2012, funded by the Engineering and Physical Sciences Research Council 'Bridging the Gaps' Award in response to a proposal by Simin Davoudi and Philip Lowe, delivered in partnership with Dermot Roddy, Guy Garrod, Tanja Pless-Mulloli, Margaret Bell and Steve Bull at the Newcastle Institute for Research on Sustainability (NIReS).

Developing a Research Agenda for Retrofitting Sustainability

Contents

Introduction

The *Retrofitting Sustainability* project was supported by the EPSRC to formulate an interdisciplinary research agenda on retrofitting the built environment. This working paper brings together three commissioned literature reviews and outputs from discussions held in a number of internal workshops and a two-day open seminar at the Newcastle Institute for Research on Sustainability.

The project was developed in the context of the EPSRC *Process, Environment and Sustainability* Programme by a network of engineers, architects, planners, public health experts and social scientists within the Institute to explore what retrofitting sustainability means, technically, economically and socially. Its focus was the achievement of improved levels of resource efficiency within the existing form and fabric of the built environment in post-industrial societies, placing particular emphasis on the theme of energy.

The project began with the premise that retrofitting is essentially a combination of engineering techniques, whether for single dwellings, streets, neighbourhoods, cities or regions. These techniques tend to be based on explicit assumptions about technical effectiveness and cost efficiency and largely implicit assumptions about models and processes of socio-economic and institutional change, and their consequences. Its task was to explore these assumptions, particularly in the context of Newcastle and the North East, and to identify opportunities and priorities for further research.

An initial workshop for network members highlighted the range of ways in which the term is used and the complexity of engaging with the many different scales of 'retrofitting' activities. It also revealed particular shared interest in research at the interface of technological change, social and individual behaviours and issues of social and environmental justice and governance. This was described as moving from the *"develop clever technology and persuade people to use it"* or *"decide – announce – defend"* models to new models integrating policy, technology and social processes. In this context, three literature reviews were prepared which concentrated on identifying:

1. How the concept of retrofitting in the built environment has developed from the perspectives of engineering, architecture, public health, transport, planning and related social science literatures (Review 1).
2. Models and theories of behavioural drivers and energy transitions (Review 2).
3. Social justice issues arising from central and local government initiatives for retrofitting the built environment (Review 3).

Overview

This overview describes the outputs of both internal and external discussions conducted through the project, combined with the findings of the three literature reviews, and outlines an emerging programme for further research on retrofitting sustainability.

A growing agenda

Energy efficiency has been a primary driver for retrofit activity. The Foresight Report (2008) *Sustainable Energy Management in the Built Environment*, commissioned by the Government Office for Science, contrasted four major scenarios for future energy use in UK buildings and infrastructure. All four involved retrofitting, i.e. the modification of existing buildings and infrastructure to support a low carbon society, some to much greater extents than others. Indeed, the 'resourceful regions' scenario required that "retrofitting rather than new build is the preferred approach". The conclusions of the Foresight study promoted the concept of "integrated retrofitting", combining "targeted information provision, attention to how people and firms currently assess and consider their building energy efficiency; appropriate financial incentives; tighter regulation and enhanced capacity within…retrofitting firms" (p.161). Similarly the European Commission's *Energy Roadmap 2050* (2011) stressed that the prime focus for transforming European energy systems was the improvement of energy efficiency, with consumer and business behaviour expected to be as important as the performance of technologies and materials and with local organisations and cities playing much greater roles in the functioning of energy systems. While the UK has implemented a range of energy efficiency programmes over the last few years, as discussed in Review 3, the latest progress report to Parliament by the Committee on Climate Change (2012) calls for an urgent step change in the delivery of low carbon economies and lifestyles.

However, as Review 1 demonstrates, retrofitting is not just about energy objectives, but also, for example, climate change adaptation, resilience to flood, earthquake or security threats, health, mobility and lifestyle change. Greater Manchester's retrofit policy has built on its 'Mini Stern' Report to develop a predominantly economic rationale for undertaking retrofit, driven by 'low carbon' job-creation opportunities (Hodson and Marvin, 2012). In this context, the *Retrofit 2050* research project, currently being undertaken by the Universities of Salford, Cardiff, Durham, Cambridge and Oxford Brookes (see Annex), specifically asks 'how do we organise retrofitting as systemic change?" in the landscape of national policy, city partnerships, community activism, markets and consumers.

Review 3 suggests however, that uncertainty and inherent tensions about the technological, social and economic potential of retrofitting continue to underpin a somewhat reticent and piecemeal policy approach. This reflects a narrow view of both the system and the objectives involved, focused on building performance to the exclusion, for instance, of the achievement of overall carbon outcomes or related outcomes, such as warmth and health or economic regeneration. As a result, current retrofitting activity is largely incremental, opportunistic and fragmented, despite the interest of large city partnerships in using the retrofit agenda to develop their economic, housing and environmental strategies. There appears to be strong dissociation between national and local priorities, e.g. to address carbon emissions, fuel poverty, security or 'green economies'. Such non-alignment of retrofit objectives can lead to perverse outcomes such as wealthier households being subsidised to produce energy by increases in the fuel bills of poorer households.

Research challenges

In this context, the promotion of retrofit of the built environment as a major area for increased empirical research by the UK Research Councils has been an important step forward. This has included the recognition that a major challenge for such research lies at the interface of technology and the way in which objectives for urban/rural systems are identified, negotiated and are either agreed or continue to conflict. The interaction between actors, systems and technologies opens up important new areas e.g. the way in which new visualisations of the relationship between householder behaviour, the energy performance of their home and related outcomes might feedback and influence both household and wider social behaviours.

Models of retrofit

Indeed conceptualisations and data about existing systems are key to the understanding of the potential and nature of retrofit activity. What do we understand as retrofit rather than replacement or redevelopment? *Retrofitting* involves bringing together "new and old" to create hybrid systems that meet new objectives while still fulfilling at least some of the functions delivered by the original system. While *development* involves the establishment of a new system, *replacement* or *redevelopment* eradicates and replaces an older one. Retrofitting, on the other hand, involves engaging creatively with existing systems to meet the demands of changed, and changing, operating contexts and needs.

In the retrofitting process, the new objectives driving change 'interrogate' an existing system. They ask can it deliver these objectives and, if not, what needs to be changed in order for it to do so; what can stay the same; what do we need to consider in order to decide? At the same time what will the system lose through changing objectives and how can loss be minimised? Can the new objectives be modified, reprioritised or reframed? This can be read as a form of inertia but it can also be seen as a process of maximising conservation of materials, flow and functionality i.e. as a form of homeostasis. From this perspective, retrofit models of change are inherently ‘systemic’ or ‘metabolic’ models i.e. they are based on the premise of maintaining “functioning systems” as opposed to, for instance, linear progressions maximising competition and redundancy. On this basis, for instance, retrofit decision-making may be expected to reduce vulnerability (e.g. to fluctuating external supply and prices) and maximise resilience (e.g. by closing resource flow loops).

This is underlined in Review 1 by the account of research activity developing retrofit decision-making tools for building owners and occupiers. At the community or neighbourhood level, social and institutional capacity to engage in integrated decision-making for change is increasingly recognised as a critical component of delivery. At the city-level there appears to be particular potential for exploring the relationship between retrofit approaches and analytical concepts of eco-design, urban metabolism and territorial ecology. A core question at all these levels is what retrofit interventions have the greatest overall benefit in not only environmental (e.g. carbon) but also social and economic terms? How can we best design and evaluate such interventions. The role of information and communications technologies is expected to be important as part of the wider governance and knowledge processes involved.

The Sustainable Urban Metabolisms in Europe (SUME) project asked comparable questions about systemic change pathways to sustainable urban living, as Retrofit 2050, highlighting issues of path-dependency for settlements and the sheer diversity of potential across ‘high growth’ and ‘low growth’ cities in Europe (see Annex). It specifically recommends strategies of sub-centre transformation for low-growth cities such as Newcastle. As Review 1 further highlights, retrofit dynamics at one scalar level may have critical implications for retrofit options at either higher or lower resolutions of scale.

Retrofitting infrastructure

The reviews picked up relatively little about research or policy concerning either the retrofitting of infrastructures or infrastructure for retrofit although this figured strongly in internal discussions. To some extent, major infrastructure delivery is still dominated by a linear process of *design*, *construction*, *maintenance*, *decommission and replacement*. What therefore does retrofit mean in the context of major infrastructure, such as transport? Consideration of the 4M and SECURE projects (Annex), which are working to develop robust interdisciplinary approaches to infrastructure assessment and design, suggests that retrofit requires a reconfiguring of design drivers around systemic objectives in which measurements of individual and social well-being move to centre-stage. This is a counterforce to a concurrent emphasis on resource and energy ‘efficiency’ that focuses on the maximisation of performance for minimum inputs. It asks who decides what performances are required and who decides what trade-offs are acceptable? Research is needed to develop the evidence bases that can help such decisions to be both framed and understood, including the technological bases for achieving acceptable 'trade-offs'. For example, the premature death toll due to poor air quality in the UK is estimated at up to 50,000 people per year (House of Commons, 2010), highlighting the potential link between carbon policy and air quality objectives.

The links between health, poverty and environmental objectives were a core theme for project discussions, as highlighted by Review 3. In this context, concepts of 'holistic household retrofit' and 'total community retrofit' begin to reflect back on the very nature of what is understood as 'the household' and 'the community'. Are we still asking the right questions? Are there alternative approaches to meeting energy needs that are still to be developed? Can we use technology to develop new imaginaries for low carbon behaviour? Are there new potential conceptions of independence and interdependence e.g. to what extent can a household generate and take control of its own energy needs, including those needed for transport; to what extent does this rely on community or wider system dynamics? Access to information through digital technology is expected to play a major role in the way in which such issues play out. To some extent this is about access to information upon which to base decisions about comparative performance of technologies. But, at least as significantly, it will be within social and cultural terms that such information is made sense of and acted upon by different social groups.

Behaviour, social capacity and learning

Review 2 examined the nature of drivers of behaviour change that need to be understood in retrofitting for sustainable energy use by unpicking the relationships between individual psychology, social behaviours and socio-technical systems. It demonstrates the complex impacts of technological change on energy demand behaviours, including the "rebound effect" in which greater energy efficiency appears to unlock greater individual and/or social demand for ever more energy services and goods. Behavioural models also involve the interplay of multiple objectives, perceptions of "self-efficacy" and "world views". In turn these interact with a broad range of contextual factors including social norms and expectations. These models have informed interest in "social marketing" and in feedback and monitoring approaches aimed at the tailoring of interventions that are sensitive to specific sets of individual and contextual characteristics.

At the same time, there are concerns that widely used behaviour change models reflect a dominant, expert-led technocratic approach to environmental policy and management. These concerns refer to a multi-level perspective that recognises behaviour as only one element of a conglomeration of technologies, institutional practices, rules, norms and behaviours that form a stable regime resistant to substantial change. According to this approach, effective governance interventions need to engage with networks of all relevant actors to jointly explore shared recognition of future scenarios and promote innovation, learning, feedback and adaptation. This suggests that there need to be a multiple experiments with different bundles of retrofit technologies and institutional and social practices supported at a multitude of levels, including different types of:

- Financial incentive
- Ownership/management
- Technology
- Infrastructure networks
- Operational frameworks and user requirements
- Regulation and planning practice
- Supply chains.

At the same time, social and institutional processes of decision-making about retrofitting frame new understandings of drivers and relationships. In response to increasing recognition of the links between poverty, health, regeneration and various aspects of environmental protection, there could be new opportunities, based on new public health duties of local authorities, for retrofitting to improve public health functions for mobility, air quality and residential comfort. In this context, shared learning frameworks, within which public, private and research sectors can work together, are critical to delivery. Project discussions about processes and opportunities for piloting developing technologies and materials suggest that this could benefit from the further development of networking between researchers, business and the third sector in the North East.

Priority areas for collaborative research

Hodson and Marvin (2010) suggest a place-sensitive, empirical framework for urban retrofit as being:

1. How different contexts affect the pressures for retrofitting and how barriers can be overcome.
2. The issues and challenges of up-scaling retrofitting to systematic activity.
3. Different capacities and capabilities to deliver.

At the same time it is important to engage with new concepts of what constitutes *retrofit.* Changing technologies (especially communications technologies) are reshaping individual and organisational conceptualisations of what constitutes the home, the workplace, the neighbourhood and the city? What is the role of retrofit in the context of such change and how might we begin to design new-build and infrastructure for ‘future retrofit’. This is expected to unlock new opportunities for retrofit activity.

The risk that incremental small-scale retrofitting can lock development into path-dependent patterns that are fundamentally unsustainable on a larger scale is highlighted throughout the reviews in this paper. This points to the importance of whole system perspectives that may help to avoid such lock-in. As Review 1 highlights, the main emphasis of retrofit research has been on the development of retrofit technologies and products, offering very significant potentials for cutting carbon emissions. But what can such potentials actually deliver *in situ*? There remains a lack of empirical evidence about the performance of technologies in the lived environment, especially in terms of whole area case studies. Indeed, the distinction between household-centred and area-based approaches to retrofitting sustainability is likely to prove at best an artificial one.

Instead, evaluation of retrofitting potential and delivery will need to engage with the interactions between scales. Such evaluation faces key challenges especially where complex multiple objectives come into play, as they invariably do when technologies are applied in 'real life' locations. In this context, the challenge becomes to identify research designs that can involve stakeholders, managers and residents in co-producing technological, policy and management packages that cut carbon intensity in the context of a whole framework of resource-use objectives. Such approaches can identify or demonstrate where the biggest or most rapid retrofit impacts can be made and explore the potential to prioritise retrofitting activity (spatially, sectorally and/or temporally). They also offer the potential to link to research into "changing lifestyles" and relationships between socio-cultural and individual expectations for energy and resource use.

While they face major practical challenges, including highly variable databases on building stock, there is considerable untapped and growing potential to pilot new low carbon technologies with local authorities, Green Deal consortia and businesses. Network discussions indicate the potential to develop a 'retrofit learning platform' for the North East, bringing together data from a broad range of stakeholders, including local authorities, health trusts, universities, and third sector organisations. Urban and regional modelling, as developed in SUME, SECURE and Carbon Routemap (Annex), offer key resources for the development of learning frameworks, feeding into the design, development and evaluation of decision-making tools and other resources for stakeholder engagement in policy and programme design and delivery.

Whole system research for city retrofit will develop our understanding of the relationship between urban restructuring, retrofit and resilience. In this context, given whole life-cycle costs of building materials on the one hand and the significance of location to the functioning of buildings and urban/rural systems on the other hand, is demolition ever justified and if so, when? The interaction between new development and retrofit activities and the whole system (neighbourhood and city) scale suggests that retrofit activity should be fully integrated with design, management and planning objectives for energy and resource use. This requires analysis of interactions between scales of intervention, in technological, economic and social terms, and between multiple objectives. There is, for instance, considerable potential for development of options for retrofit of "heritage" areas and understanding its social and market impacts.

An integrative approach will necessitate a focus on individual 'lifestyles' and behaviour as well as institutional practices, technological development and systems of provision. This will include assessment of differential impacts of energy policies, programmes and projects on end user responses and behaviours. A key priority is assessment of the retrofit work that has been delivered to date through fuel poverty measures and detailed case studies and evaluation of how central and local government action, combined with private and third sector activities for retrofitting, play out in terms of social and environmental justice and health/wellbeing inequalities. There is considerable potential to develop methodologies to test retrofit scenarios against emerging measures of environmental and social justice. These in turn can feed into assessment of institutional architecture and governance mechanisms for developing and delivering retrofitting.

A key focus should be on the development and testing of options for "sub-centre transformation" of the built environment, in the context of whole-system approaches to energy and resource use in 'low growth urban areas' such as those in the North East of England. For instance, there is particular potential for a pilot heating strategy for an area of Newcastle, drawing on good datasets, local authority commitment and developing models. This would enable detailed exploration of the relationships between transformation of energy demand in the built environment and transformation of systems of energy supply. As Review 1 highlights, the relationship between decentralized and micro energy generation and distribution and retrofit for energy demand reduction and other environmental objectives remains very much under-researched.

This paper demonstrates that retrofitting sustainability has a fundamentally social meaning. Thus, for example, the retrofit of an area could involve almost complete replacement of the buildings and systems involved, while maintaining the community and social functioning of that area. This perspective on retrofit emphasises not only the social and behavioural processes of retrofit at building, neighbourhood and city scales but also the potential for collaborative and participatory methodologies for research on retrofit activity at all scales. It offers a transformative perspective on processes of urban change, with implications not only for existing areas but also for the design of new urban areas.

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Review 1: Concepts of Retrofit in the Built Environment

Introduction

This review aims to identify how the concept of retrofit is being used from engineering, architecture, public health, transport, planning and related social science perspectives. According to the Oxford dictionary, the origins of the term 'retrofit' go back to the 1950s, as a combination of 'retroactive' and 'refit', meaning to '*add (a component or accessory) to something that did not have it when manufactured.*' As shown in Table 1.1, the use of the concept of retrofit in the literature was traced back to 1970s when the main focus of research was to evaluate how the built environment could be retrofitted for energy conservation, i.e. to significantly reduce energy consumption. It was first used widely in relation to sustainability and climate change in the 1990s. Its use in relation to green infrastructure, building materials and transportation appears to date mainly from the 2000's onwards.

Table 1.1 Chronological origins of term 'retrofit' in review literature

Themes	1970s	1980s	1990s	2000s
Energy conservation for urban housing	■			
Energy conservation in commercial, institutional and industrial buildings		■		
Climate change and built environment			■	
Water management			■	
Sustainable transportation/urban mobility			■	
Renewable energy			■	
Management of building sector			■	
Passive ventilation			■	
Green roof				■
Seismic				■
Green infrastructure				■
Urban drainage				■
Retrofitting sprawl/suburbia				■

The terms 'refurbishment' and 'renovation' are often used as synonyms in describing the retrofit of buildings (Gupta and Chandiwala, 2010; Power, 2008; Kristl and Zbasnik-Senegacnik, 2002; Ouyang et al, 2011b) while Gleeson (2011) describes the 'retrofitting' industry as an emerging one in the context of the mainstream construction/ refurbishment industry in the UK, with a number of factors driving its emergence as a separate market.

There is a very substantial engineering literature on technologies that can be retrofitted to reduce carbon emissions in the built environment. At the same time a growing body of literature from the social sciences addresses how human behaviour is critical to the performance of retrofitted built environments. The literature also reveals a relatively small number of multi-disciplinary studies aimed at exploring the economic feasibility and social implications of retrofitting. This review looks at three scales of retrofit intervention: individual structures, district or neighbourhood levels, and city or city region levels or retrofitting activity.

Retrofit Interventions in the Built Environment: Individual Buildings

The technologies, design and evaluation processes and the behavioural and decision-making issues associated with retrofit interventions at the building level can be summarised according to the themes and sub-themes identified in Table 1.2. These range from the development and assessment of technical aspects of retrofit to research into complex drivers of retrofit uptake and behaviour.

Table 1.2 Themes and Sub-themes identified for retrofitting of individual structures

Theme	Main Sub-Themes
Energy Retrofit Technologies and Measures (ERMs)	Building envelope and materials Window-wall ratio, insulation level of wall and roof, thermal resistance and solar heat gain of window, degree of air tightness, presence of operable windows; Innovative and robust thermal insulating materials; Effectiveness of ERMs; Interaction of ERMs Combination with use of renewable energies
Retrofit Design	Energy performance/ Energy efficiency Design decision-making on single or multiple changes; Modelling and software simulation in decision-making tools; Uncertainties in modelling process;

	Socio-economic aspects; Interactive investigation tools;
End-user's decision making	Owner's investment decisions; Occupants feedback; Learning processes for building owner, occupant, designer and building manager; Factors driving peoples' energy use behaviour; Consumer behaviour;
Health	Fuel poverty; winter mortality rates; vulnerable households

Energy Retrofit Technologies

Gleeson et al (2011) define the term 'retrofit' as:

> *the refurbishment of buildings to improve their sustainability, in particular their energy efficiency and carbon dioxide emissions. Retrofitting takes place sometime after original construction and incorporates or substitutes more up-to-date parts and new elements where appropriate. Retrofitting technologies include those that are 'fit and forget' and those that require attention to control systems, management and maintenance. Retrofit elements may include those that contribute to wider networked decentralized energy systems such as PV panels (with or without the incentive of feed-in tariffs).*

In developed countries, it is estimated that over 50% of residential energy consumption is used in space heating, over 20% is accounted for by appliances (including air conditioning), while hot water, lighting and cooking account for 16%, 5% and 5% respectively (Booth et al, 2012). A review of building retrofit technologies by Power (2008) concluded that it is feasible to cut the energy performance of existing UK homes by 60% or more. Harvey (2009) reviews the literature on energy savings that can be achieved through changes in envelope properties, efficiency of individual energy using devices, occupant behaviour and operation of the building system in both residential and commercial sectors. He concludes that reductions in the energy intensity of existing buildings by factors of 2-3 can be achieved through comprehensive modifications to the building envelope, including the replacement of curtain walls and the installation of double-skin facades. Yalcintas and Kaya (2009) found energy savings from retrofit projects ranging from 28% to 61% for individual equipment retrofits.

Energy-relevant factors of building envelopes include window-wall ratio, insulation levels of walls and roofs, the thermal resistance and solar heat gain coefficient of windows, the degree of air-tightness to prevent unwanted exchange of air between inside and outside, and the presence or absence of operable windows. Li et al (2009) discuss the improvement of building envelopes for buildings in multiple sectors. A number of studies focus on improving thermal insulation of particular materials or wall components or even the whole wall system to improve users' natural comfort and reduce dependency on energy consumption (Sveipe et al, 2011; Finch et al., 2006). Components such as window and wall systems are also discussed in order to investigate how openings in the wall contribute towards users' comfort in different microclimates (Caesar et al., 2010; Howden-Chapman et al., 2009; Gustafsson and Bojic, 1997). Other studies report on the design of building envelopes in hot climates (Friess et al,2012; Al-Ragom, 2003; Goswami and Mathur, 1995), while Zhou and Gong (2011) and Yu et al (2009) describe approaches to design in China.

In this context, studies from material science focus on developing innovative and robust highly thermal insulating materials (Jelle et al, 2010). Other studies under this theme address the contribution of renewable energy technologies to retrofitting, with particular emphasis on solar energy (Albatici, 2009; Yalcintas and Kaya, 2009; Goodfield et al., 2007; Gustafsson, 2001; Argiriou et al., 1997).

Designing Building Retrofit

Modelling and software simulations of whole buildings are used to support design and evaluation processes (Olofsson and Mahlia, 2012; Porteous and Menon, 2008; Medina et al., 1998; Chidiac et al., 2011b; Verbeeck and Hens, 2005). As Petersdorff et al (2006) show, the focus is on the measurement of the energy performance of the building. Li et al (2009) discuss feasible energy saving retrofitting strategies and technologies for existing public buildings, with particular emphasis on the building envelope, heating, ventilation, air conditioning and lighting systems, using software simulation to calculate energy saving and payback period.

Olofsson and Mahlia (2012) explore tools for interactive investigation of building energy performance. They provide information on savings based on retrofit measures using software applied to single family buildings. They demonstrate how decisions early in the design process can have decisive importance for final energy performance. Chidiac et al (2011b) identify climate, occupancy, heating and cooling systems, envelope properties and building geometry as significantly influencing performance. The effectiveness of multiple ERMs also depends on interactions between them (Chidiac et al., 2011a).

Hoicka and Parker (2011) consider whether a building should be retrofitted as a system (multiple energy efficiency changes) or whether one should focus on single changes associated with large energy savings. Their research assessed whether homeowners treated the 'house as a system', that is, whether they made multiple energy efficiency changes (e.g., increasing insulation in the ceiling, foundations or main walls, upgrading windows and doors, air sealing, improving heating, ventilation, air conditioning, or domestic water heating systems) or focused on a single change associated with large energy savings, such as changing their heating furnace. Other studies deal with overall residential building heating and insulation systems (Yan et al., 2011; Yu et al., 2009; Zhao et al., 2009; Rolfsman and Gustafsson, 2003; Summers et al., 1996; Gustafsson and Karlsson, 1989).

There are numerous studies on retrofitting commercial buildings (Chidiac et al., 2011b; Chidiac et al., 2011a; Chow and Levermore, 2010; Harvey, 2009). This includes office buildings (Koranteng and Mahdavi, 2011; Keeton, 2010; Lam et al., 2010; Rhoads, 2010; Corgnati et al., 2009b; Jenkins et al., 2009; Lam et al., 2008), hospitals (Bizzarri, 2006) and hotels (Millar and Baloglu, 2011; Li et al., 2009; Kristl and Zbasnik-Senegacnik, 2002; Santamouris et al., 1996). Xu et al (2011) identifies Energy Performance Contracting (EPC) as a 'win-win mechanism' to organize building energy efficiency retrofit projects and develops a set of critical success factors of EPC for sustainable energy efficiency retrofit of hotel buildings in China. Chow and Levermore (2010) discuss how office buildings in UK will cope with future climate change and its impact on heating and cooling load. They show that different future climate scenarios and building regulations will significantly contribute towards both use and performance.

End-users' decision making

Studies of how owners and tenants make decisions about incorporating and using retrofit technologies reveal an emphasis on economic evaluations. However, as Harvey (2009) stresses, comprehensive retrofits of buildings are generally done for many reasons in addition to reducing energy costs. Ongoing maintenance, repair and upgrading are all important factors, as well as changes in management and use. These are particularly relevant in historic buildings (Foster et al, 2011; Lloyd-Jones, 2010; Lubeck and Francis, 2010).

Gleeson et al (2011) use the terms 'shallow', 'mid-level' and 'deep retrofitting' to describe varying standards for carbon reduction, with the latter offering the greatest carbon reductions but also the greatest disruption. They conclude from their review that beyond a certain "tipping point" of retrofit intervention, the high cost-to-benefit ratios and the high levels of disruption to occupants are likely to prevent uptake. Amstalden et al (2007) analyse the profitability of residential sector retrofit investment from the house owners' perspective in a Swiss study and conclude with an assessment of the economic potential of retrofitting, identification of the most influential factors, and specific implications for house owners and investors. Ouyang et al (2011) conducted an economic analysis of upgrading aging residential buildings in China, including a model for distribution of investment costs and benefits.

Costs for major refurbishments of UK properties indicate an average of £40,000 per house to achieve 80% carbon dioxide reductions (Bernier et al 2010, p.204). This study notes that while prices of measures to upgrade homes for energy efficiency are generally well known, the paybacks involved with such investments, both in financial and carbon dioxide reduction terms, are less clear and further analysis of cost-benefit and payback is needed. The authors suggest a multi-stage intervention model, pursuing the most cost-effective measures immediately, while making accommodation for a second retrofit of more advanced zero-carbon technologies once prices have fallen.

Jaggs and Palmer (2000) proposed Energy Performance Indoor Environmental Quality Retrofit (EPIEQR) as a methodology to guide apartment owners in decision making on refurbishment and retrofitting their building stock. Menassa (2011) proposed a methodology that aims to provide decision makers with the flexibility to determine, prioritize and evaluate required retrofits over time, recommending retrofit measures that can be implemented immediately and others that should be delayed. Bernier et al (2010) propose a building rating system to assess overall sustainability merits of retrofitting existing homes and the success of retrofit measures. They describe the term 'retrofit' as meaning 'renovation that stretches….to address sustainability matters' (p197) and identified 63 issues across 8 categories, including energy, water and waste. They caution against the tendency for rating systems to oversimplify complex sustainability matters but confidently promote their value in effecting change to a low carbon built environment.

There are a significant number of studies on users' decision-making and behaviour in retrofitting or managing energy systems in their own houses (Sunnika-Blank et al, 2012, Gupta and Chandiwala, 2010; Li, 2009; McMakin et al., 2002; Haas et al., 1998; Gonzales et al., 1988; Hirst et al., 1985; Hirst, 1984; Winett and Neale, 1979). In their review of energy conservation literature, McMakin et al (2002) concluded that people are more likely to adopt energy-efficiency behaviours if:

- Energy efficiency can be viewed in terms of benefits to themselves rather than curtailment of use, especially in terms of thermal comfort and health;
- Energy use and savings are made visible, thus providing goals and motives where they did not previously exist; and
- Information is conveyed in a vivid, salient and personal format, including visual modelling of specific actions to be taken.

In this context they emphasise that common group identities can lead to improved performance by individuals and that effective intervention efforts should explicitly include the characteristics of the targeted living situation and its residents (p851). Ostrom (2012) argues that building a strong commitment to finding ways of reducing individual emissions can be most effectively undertaken in small- to medium-scale governance units that are linked together through information networks and monitoring at all levels. The interaction between energy behaviours at the individual level and the governance of energy retrofit is discussed in detail in Review 2 below.

Health

In 2007, there were an estimated 4 million households in the UK considered to be in fuel poverty, i.e. those who have to spend more than 10% of income to achieve adequate heating to maintain health. The link between inadequate heating, causing damp, cold and mouldy houses, and poor health has been widely highlighted. Targeting energy efficiency retrofit on low-income households is therefore expected to deliver health benefits (Booth et al 2012, Jenkins, 2010, Howden-Chapman et al, 2007; Howden-Chapman et al., 2009; Mathews and van Why, 1996). Retrofit interventions can also improve air quality (Kumar et al., 2011; Corgnati et al., 2009a; Carrer et al., 2005).

Retrofit Interventions in the Built Environment: Neighbourhood and District Scales

There is an increasing emphasis in the literature on retrofitting at neighbourhood or district levels of intervention. Table 1.3 identifies the main themes and sub-themes. These include a focus on retrofit to reduce the energy intensity of urban sprawl, influences of place properties on behaviour and the impact of retrofit on local property markets. Very recent studies on suburbs are focusing on the significance of vulnerability to climate change as an increasingly recognized issue for retrofitting.

Table 1.3 Themes identified for retrofitting at neighbourhood or district level

Theme	**Main sub-themes**
Community or neighbourhood regeneration	Demolition/refurbishment debates; Low carbon and 'eco-' neighbourhoods Retrofit of core urban areas
Retrofit of sprawl/suburbs	Retrofitting existing suburban housing stock; Retrofitting inadequate building regulation, fragmented ownership and management of land and housing; Coordinating multi-actor partnerships, developing political will, encouraging behaviour change. Adaptive capacity
Market value	Improved market value of property both at individual and district level for developer and local government decision making;

Neighbourhood Renewal

Power (2008) reviews the debate over the choice between demolition and refurbishment in improving the environmental performance of residential stock at the local or neighbourhood level. In particular, she notes that the roles of gradual incremental renewal and neighbourhood management are undervalued and underlines the 'urgency of developing much higher standards for renovation of virtually all existing homes' (p4492). In this context, retrofit is seen as part of a wider process of neighbourhood renewal, adding value and attractiveness, with associated benefits on street conditions, social mixing, service quality, local transport and schools and compares favourably with demolition and new-build in terms of a broad range of social, economic and environmental factors, including local employment. Indeed Power argues that residential retrofit should shape housing policy (p4497). Winston (2010) similarly argues that the emphasis should be on renovating poor housing rather than demolishing it and on integrating housing, land-use and transportation policies, with a view to achieving densities that support the feasibility of public transport.

Friesen et al, in Walliser et al (2012), describe recent Swedish experience of renovating an early 1970s social housing neighbourhood of sixteen prefabricated apartment blocks to passive house standard. Retrofit objectives included energy efficiency and comfort alongside improved physical accessibility for residents with reduced mobility. A high value was placed on maintaining existing social capital. They highlight both the benefits and conflicts for sustainability of extensive retrofit as opposed to demolition and rebuild and the importance of maintenance of sense of place and identity as an important outcome of retrofit approaches based on high levels of resident participation.

Lloyd-Jones, T. (2010) evaluates what measures can be employed for sustainable retrofitting and refurbishment in historic, mixed-use urban areas, given the complexity of their built form and policy constraints, using Soho in London as a case study. He notes preliminary estimates suggest reductions in the range of 30–60% might be possible through basic building fabric improvements and energy supply measures (e.g. CHP) and highlights the need for more area-based modelling and a finer-grained classification of the key aspects of urban form and activity to provide targeted advice and information, based on a typology of historic building types, for owners and occupiers.

Retrofit of sprawl/suburbs

With compact cities promoted as the most sustainable urban form, existing urban sprawl represent a major challenge to planners seeking to support cuts in carbon emissions. Indeed, as Williams et al (2010) point out, in most developed countries, suburban areas contain the majority of urban housing and these areas are energy-and land-rich, with built form layouts that encourage car use and discourage walking and cycling. Despres et al (2004) describe a transdisciplinary, participative design process used to plan for the retrofit of the city of Quebec's post-war inner-city suburbs. Key objectives included cutting carbon emissions whilst meeting a range of social and environmental needs. They argue that retrofit of existing suburbs calls for a higher citizen involvement than that required when dealing with new developments, not least because their residents are "specialists of everyday life" (p474). In a retrospective evaluation of the process they argue that it has contributed successfully to the development of common objectives and specific proposals for retrofitting the suburbs and increased capacity for action (Despres et al., 2008). They highlight the importance of widely shared information and "a new communicative and interdisciplinary approach to decision-making" (p340).

Emily Talen (2011) notes that *Time* magazine rated "recycling suburbia" as a leading "idea changing the world" , and that "sprawl retrofit" in the US has been long promoted by the Congress for the New Urbanism. Related terms are "sustainable suburbs" and "sprawl repair". She suggests a planning method that puts the sprawl retrofit project into a larger planning framework, evaluating the strengths and weaknesses of places in relative terms, taking different kinds of nodes into consideration. This study concludes that intervention in potential retrofit locations will involve both neighbourhood and site-scale design, and proposes suggestions for code reform, intensification of land use around nodes, public investment in civic space, traffic calming, and incentives for private development.

Retrofitting of suburbia is described by Dunham-Jones and Williamson (2009) as going beyond simply installing new elements to an existing context towards 'the idea of systemic, long-lasting transformative change' (quoted in Rice, 2010, p194). Rice goes on to describe modelling work on suburban retrofit for two London boroughs to accommodate the recommendations of the UK's Urban Task Force (1999) for urban densification. He distinguishes between 'restructuring' and 'retrofitting', with the latter involving a process of 'soft-intensification' of neighbourhood structures in order to support higher levels of accessibility by walking and public transport.

Vall-Casas et al (2011) emphasise "the morphology, history and culture of places" in retrofitting suburbia. In this context they argue that "a fragmented approach that focuses on individual projects tends to neglect the identification of integrative frameworks" and suggest that this may be achieved by "developing open spaces in a manner that …..may provide a platform for multiple projects and a more global retrofitting approach" (p172). They conclude that the potential role of cultural and historical patterns as "retrofitting tools" is under-researched and that these patterns (watercourses, historical tracks etcetera) offer the potential to combine infill projects and heritage recovery programmes to improve the social and economic bases for retrofitting.

Williams et al (2010) explore suburban retrofitting challenges in the context of potential conflicts between carbon reduction agendas and climate change adaptation needs in the context of 'compact city' discourses (see Table 1.4). Pressures for increased cooling and improved drainage and water supply are highlighted. Thus, rather than promoting high-density housing and urban infill, space may be required for cooling and green and blue infrastructure in suburbs. The authors also elaborate on issues of retrofitting existing housing stock, the fragmented ownership and management of land and housing, and the slow pace of change in suburban areas in the UK, and emphasise the social change issues of coordinating multi-actor partnership, developing political will, generating public acceptance, and encouraging behaviour change (see also SNACC project in Annex). They echo Despres' emphasis on the agency of residents, arguing that "suburbs, far more than urban centres, are 'co-produced'….by homeowners, public bodies and private companies, through the dual process of *autonomous* adaptations (i.e. those done...for individual benefits) and *planned* adaptations (undertaken by public bodies…for the public good)" (p.4).

Table 1.4: Examples of Neighbourhood/Suburban Retrofit Actions for Combined Climate Change Action

Retrofit Actions	**Related Outcomes**
Elevation of properties	Response to risk of alluvial or fluvial flooding; creation of naturally cooled outdoor space.
Demolition of properties	Remove flood risk on flood plains; release productive land; remove car- dependent areas; create opportunities for new infrastructure
Construction of conservatory extensions	Utilise passive solar gain; provide indoor food growing areas; improve indoor air quality
Installation of green roofs	Increased carbon absorption and cooling; reduced rainwater run-off; increased biodiversity
Grey water and rainwater capture systems	Decreased energy costs for water treatment and increased security of supply
Installation of local/district heating or CHP based on renewables and/or more effective use of fossil fuels	Reduced carbon emissions from generation and distribution; Increased energy security
Installation of waste-to-energy plants	Reduced carbon emissions through substitution of fossil fuels; Use of methane; Reduced waste transport and landfill
Integration of composting facilities into	Reduced waste transport and unlocking

public and private outdoor space	of carbon through use of peat.
Development of allotments and garden plots	Reduce food miles and support healthy eating and exercise
Development and conservation of green space	Increase carbon absorption; shelter and cooling effects; improve drainage; reduce run-off; increase biodiversity
Construction and reinforcement of hard and soft flood defences	Protect key infrastructure, especially local energy generation and public transport; increase biodiversity; health and economic benefits
Installation of Sustainable Urban Drainage Systems, Ponds and Reservoirs	Carbon absorption; decreased energy costs for water treatment and water supply; flood control; increased biodiversity; localized cooling; increased drainage capacity to prevent contamination

Adapted from Williams et al (2010) p. 9. See also Ghosh and Head (2009)

Smith and Hopkins (2010) stress the need to evaluate suburban communities' or localities' capacity to identify and implement retrofit measures. They draw on the literature of neighbourhood governance and use insights from actor-network theory to understand differing conceptualisations of 'neighbourhood' that are at play when thinking about collective actions. Williams et al. (2011) argue that attempting to simultaneously address the concepts of both climate change mitigation and adaptation in terms of the 'response' capacity of neighbourhoods "can raise issues of compatibility of solutions and differences in approaches, motivations and capacity" (p2). However, Head (2010) challenges the dichotomy between adaptation and mitigation in the context of 'cultural ecology', arguing that the necessary cultural changes for both will be 'extremely complex and occur at the intersection of individual, social and institutional behaviours and attitudes' (p.238), requiring more research emphasis on relational understandings of spatial and temporal scale.

Market value

Zavadskas et al., 2008 investigate how retrofitted houses improve the market value of property both at individual and district level. Amelioration of the local environment is an important factor in effective retrofitting. The market value of a retrofitted property will also depend on the condition of surrounding buildings. Ouyang et al (2011) determine the effectiveness of retrofitting based both on energy savings and the increase in market value of renovated building.

Booth et al (2012) discuss uncertainties in the modelling process arising from socio-economic aspects of the target population. They argue that existing housing stock models fail to recognize and quantify such uncertainties and their role in decision-making on retrofitting. They go on to propose a framework for incorporating uncertainties at the level of the single building and make suggestions to expand this to urban scale.

Retrofit Interventions in the Built Environment: City and City-region scales

The third level of retrofit intervention in the built environment is that of the city or city region. The focus of the literature on low carbon cities, using concepts such as 'eco-city', 'carbon-constrained city' and 'climate resilient city', has not been on processes of retrofit, although as Biello (2011) argues, referring to recent work by the C40 network of city governments, the latter is necessary to achieve significant change in urban emissions. Table 1.5 summarises the broad themes identified at the city scale.

Table 1.5. Themes identified for retrofitting at the city scale

Theme	Main sub-themes
Ecologically sustainable cities and city-regions	Eco-design; life-cycle assessment; eco-city; carbon-constrained city; resilient city; urban metabolism; industrial ecology; territorial ecology.
Urban Form and Modelling	Density and compaction; land-use/transport relationships; transport-oriented development. Whole-area versus whole-sector models.
Behaviour and culture	Environment-friendly and sustainable behaviours; cultural ecology.
Governance	Mismatch between structure of government and emerging form of governance to operationalise retrofitting; fit and lack of institutional capacity; inadequacy of legal frameworks; carbon budgets; policy tools.

Ecologically sustainable cities

Farreny et al (2011) present a methodology of urban eco-design, including processes of "urban transformation" (retrofit), characterized by "a systematic incorporation of environmental life cycle considerations into the design of urban systems", adapted from methodologies of product eco-design (p.115). In this context, they stress a lack of tools to aid in processes of both urban eco-design and retrofit. Eco-design also draws on concepts of sustainable "urban metabolism" that aim to close flows of materials, water, energy and food, while developing synergies within and outwith the city or neighbourhood area. Novotny (2010), for instance, describes the comprehensive retrofitting of water treatment systems in Singapore, El Paso (Texas) and Orange County (California) to reduce GHG emissions and other pollution, as well as to implement water conservation and reuse. In a review of studies on urban metabolism, Barles (2010) highlights the links with the development of concepts of industrial ecology and its goals of reducing loss of materials and developing 'industrial symbioses' in which the by-products of one industry become the source for raw materials or energy of another. This has led to the development of the concept of 'territorial ecology', which Barles describes as "an industrial ecology that is considered in a spatial context and that takes into account the stakeholders, and, more generally, the agents involved in material flows, questions their management methods and considers the economic and social consequences of these flows" (p.443). Farreny et al (2011) underline the importance of formal management and governance mechanisms for ensuring 'metabolic flows' through local resource management.

Hodson and Marvin (2009) examine the concept of 'urban ecological security' in recent development of city-level policy-making, with cities being seen as seeking to 're-internalise' and 're-localise' resource use by creating 'closed loops' and 'circular metabolisms' (p.201). They argue that this places a premium on cities' ability to engage and enrol new scientific knowledge and technical capability with knowledge production and exchange between cities, consultants, universities and utilities becoming critical to achieving urban ecological security. Newman (2009) describes 'resilient cities' as not only achieving lower carbon emissions but also much greater energy security through their reduced dependence on fossil fuels.

Urban Form and Modelling

As discussed above, one of the most widely promoted 'retrofit' activities at the city level is that of increasing urban compaction to deliver the most energy efficient forms of urban land use. Thus discussion of city-level retrofit is closely related to debates about the relationship between urban density and carbon emissions. As a review of the literature by Banister and Anable (2009) points out, increasing local density results in decreasing vehicle trips. At the same time, they highlight the importance of factors of mixed use and urban design quality in influencing travel patterns. Salon et al (2010), reviewing comparisons of per capita emissions between suburbs and denser urban centres also point to greater carbon efficiency in the latter.

Mitchell et al (2011), however, caution that evidence supporting direct effects of compaction on combined emissions from transport and land use is limited. Their land-use/transport interaction models for a range of spatial strategies in English city regions, found that although compaction scenarios reduced carbon emissions relative to other spatial scenarios, the differences were small. They conclude that pricing and technology measures (such as decarbonisation of the vehicle fleet) will be much more important interventions at the city region level. However, they suggest that urban form interventions at the smaller urban scale (where walking and cycling are feasible) are more significant and require more study.

From a predominantly Australian perspective, Newman (2009) argues that it is possible to envisage an exponential decline in car use in cities to 50% of current per capita passenger kilometres, as a result of a combination of rising fuel prices and substantial increases in public transport provision, based on new generation electric transit systems and their associated transit- and pedestrian-oriented development. In decarbonising the remaining vehicle fleet as part of the 'resilient city', Newman describes the role of plug-in hybrid electric vehicles (PHEVs) as part of integrated Smart Grids for renewables.

Life-cycle analysis and foot-printing models are increasingly discussed as tools on which to base the redesign and modification of cities to improve sustainability. Chester et al (2010) describe comparative life-cycle energy and emissions inventories for three U.S. metropolitan regions (San Francisco, Chicago, and New York City). These capture not only vehicle operation (direct fuel or electricity consumption) but also non-operational components (e.g., vehicle manufacturing, roadway maintenance, infrastructure operation, and material production). They found that the latter can increase emissions by as much as 20 times those of vehicle operation alone. In particular, emissions of carbon dioxide from cement production used in concrete throughout infrastructure, sulphur dioxide from the generation of electricity used, particulates in fugitive dust releases in roadway construction, and volatile organic compounds from asphalt are significant.

Sovacool and Brown (2009) review the literature on the relationship between urban density and carbon footprints and conclude that a dearth of available data on carbon emissions and comparative analysis between metropolitan areas makes it difficult to confirm or refute best practices and policies for carbon reductions. They offer a preliminary comparison of the carbon footprints of 12 metropolitan areas, ranging from London to Sao Paulo, based on emissions from vehicles, energy used in buildings, industry, agriculture, and waste. Their findings suggest that policies of densification and urbanization in developing countries may have very different emissions outcomes from those in post-industrial cities. However, overall they conclude that the most effective initiatives city planners can undertake to reduce their own footprints, apart from lowering the carbon-intensive material consumption that correlates with rising incomes, are to encourage compact growth, increased densities, sustainable transportation and mass transit, congestion pricing and driving prohibitions, cleaner electricity supply and energy efficiency programs.

In this context, Satterthwaite (2011) stresses that it is the resource use and waste generation implications of income levels and consumption choices that need more consideration than urban/rural or urban form comparisons. Frank et al (2010) argue that urban form strategies can have converging benefits for public health and climate change. Their empirical findings demonstrate increasing transit accessibility, residential density, and street connectivity as all significantly associated with more energy expended from walking and less energy generated from motorized transport.

In their study of density in Helsinki, using a life cycle assessment (LCA) approach, Heinonen et al (2011a) found that carbon dioxide equivalent emissions are substantially higher in the dense downtown area than in the surrounding suburbs, from which they conclude that increased consumption due to higher standards of living increases emissions more than higher density is able to reduce them. In further comparative work, Hillman and Ramaswami (2010) and Heinonen et al (2011b) emphasise that the carbon footprint of services, especially in the service-intensive economies and other outsourcing of manufacturing and carbon emissions, along with other cross-boundary activities, should be further examined since they cause an ever-increasing proportion of the carbon consumption of consumers.

Mori and Christodolou (2012) argue that assessments of city sustainability to inform policy development and infrastructure design must not only consider environmental, economic and social aspects but should capture external impacts (leakage effects) of a city on other areas beyond its boundaries. Their review gives a summary of existing city-level sustainability indices/indicators including: Ecological Footprint, Environmental Sustainability Index, Dashboard of Sustainability, Index of Sustainable Economic Welfare, City Development Index, Environmental Vulnerability Index (EVI), Environmental Policy Index (EPI), Living Planet Index (LPI), Environmentally-adjusted Domestic Product (EDP), and Genuine Saving (GS).

Bhatt et al (2010) describe an energy and environment systems model applied to New York City to provide a quantitative assessment of energy technology and management strategy options for reducing the carbon footprint. Keirstead and Calderon (2012), discuss the potential for using urban energy and carbon modelling tools to underpin policy and strategy. They use Newcastle-upon-Tyne as a case study and recommend further research on understanding of local building stock and energy demand to better assess potential for new technology and policy. The use of policy-relevant assessment criteria is further discussed in Calderon and Keirstead (2012).

Governance

Salon et al (2010) review the range of potential policy interventions through which city governments may affect carbon emissions from both transport and buildings. They highlight that "one major shortcoming of all this research looking at the effect of single policy changes or infrastructure investments on travel is that it does not take account of the synergies between strategies and feedback effects that occur in the real world" (p2033). However their overall conclusion is that the potential to reduce emissions through technology, infrastructure and building retrofit and behaviour change, is substantial given the right governance and policy conditions. They go on to discuss the potential for 'city carbon budgets' in providing such conditions. Under such a framework, local governments would be assigned an annual "emissions" budget by national or regional levels of government and would be required to keep local transport and buildings emissions within this budget in a manner tailored to local circumstances, supported by systems of financial and fiscal incentives, including the potential to trade emissions allowances. Romero-Lankao (2012) argues that although many cities are responding to the climate challenge, both mitigation and adaptation responses do not address many of the key drivers and determinants involved (e.g. consumption patterns and equity issues determining adaptive capacity), because of the complexity of the relevant processes operating at multiple sectoral, temporal and spatial levels.

Conclusions

This review demonstrates the breadth of the literature on retrofitting the built environment, ranging from the extensive literature on technologies designed to reduce energy consumption within single buildings across a range of sectors, to emerging concepts for the redesign of urban systems and the complex social and environmental aspects involved. Single building retrofit can range in intensity from the installation of 'smart meters' to the full-scale, comprehensive replacement of major building components. Retrofit at the broader scale of the neighbourhood and the city is increasingly reflected in current multi-disciplinary research programmes as demonstrated in the Annex.

Major emerging themes for the retrofit agenda include:

- the challenge of evaluating the costs and benefits of installing technologies, and combinations of technologies, in specific locational circumstances, at different intensities of retrofit;
- interactions between multiple objectives for retrofit, including both carbon emissions and climate risk reduction;
- interactions between scales of intervention in technological, economic and social terms;
- participative processes of retrofit at building, neighbourhood and city scales;
- collaborative and participatory methodologies for research on retrofit activity at all scales.

The definition of what constitutes retrofit at any scale appears to be as much social as technical, with the emphasis on re-engineering the performance of the built environment *in situ*, while maintaining a significant proportion of its original occupants and/or functions and characteristics. Thus retrofit design and implementation are expected to account for reduction of energy use alongside the achievement of other owner/occupant objectives. The literature highlights that economic incentives interact in complex ways with requirements such as improved health, comfort, liveability and resistance to disruption. The nature and dynamics of the interactions between occupants, managers and retrofit designers and engineers are therefore particularly significant. This is further complicated by the key role of occupants and managers in the subsequent achievement of targeted energy performance. Indeed, the 'rebound effect', through which increased technical efficiencies are negated by increased energy consumption through changes in energy behaviour and demand has been widely highlighted (see Review 2).

This social emphasis on the definition of retrofit applies at least as strongly at the neighbourhood or district scale. A number of authors point out that, like buildings, successful or vital neighbourhoods undergo continuous processes of maintenance, upgrading and change to update infrastructure and accommodate both new occupants and changing aspirations. Struggling neighbourhoods are similarly the focus of attempts at restoration or regeneration. The introduction of the concept of retrofit to these processes in the literature appears to imply new approaches and new relationships between public and private sectors aimed at the combination of environmental, social and economic agendas. The key to distinction between "restructuring" and "retrofit" seems to be the latter's sensitivity to the value of existing social, environmental and physical capital.

Immediate barriers to retrofit of the built environment at the levels of activity that can achieve necessary carbon reductions have been identified as ranging from prejudicial fiscal mechanisms to lack of both industrial and skills capacity. By their very nature, retrofit solutions in the built environment require engagement with complexity and multiple scales of intervention. At the same time, as Power (2008) cautions, the science of climate change and energy is fast moving and decentralized energy supply and micro-CHP could transform energy calculations in existing homes and communities within a few years. Indeed, in this context, the relationship between decentralized and micro energy generation and distribution and retrofit for energy demand reduction and other environmental objectives remains very much under-researched. In addition, while there may be current resistance to 'deep' retrofitting because of the disruption involved, the literature suggests that changes in incentives, linkages with other objectives (such as health and changing demographies) and commitment to new forms of retrofit management could transform the parameters underlying retrofit potentials.

At the building scale, there appears to be a need for increased research on the interactions between energy use reduction and potential problems of overheating, moisture management and air quality. The implications for the conservation of historic buildings is obvious but in fact these are issues for the retrofit of buildings of all ages. They are compounded by the challenge of building resilience in the face of climate change and the changing needs of owners and occupiers. Issues of resident perceptions and behaviour in designing and implementing retrofit also remain an important area for buildings research.

Similarly, at the neighbourhood and city level, recent research on relationships between density and energy use demonstrates the complexity of relationships between energy and materials consumption. There is a growing focus in the literature on attempts to assess and develop strategies for changing the carbon behaviour of whole urban systems. This brings together discussions of sectoral and integrated urban modelling, discussions of sustainability indicators (such as 'footprints') and approaches developed from industrial ecology: life cycle analysis and urban metabolism. However, explicit links between discussions of retrofit and waste management or avoidance seem to remain little developed.

The review highlights the need to consolidate the theoretical basis of concepts of urban metabolism, with interdisciplinary emphases on links between urban structures, metabolisms and lifestyles, the use of energy and materials, the governance of flows and the roles of local and territorial stakeholders. In this context, the literature suggests that the conceptualisations of what areas are urban, suburban and rural, and their inter-relationships, are likely to be increasingly relevant to understandings of retrofitting the built environment. This would reflect a growing emphasis on management of energy, water and materials flows, including food and waste.

The combination of sustainability retrofit with historic conservation objectives is not strongly reflected in the literature. This is surprising given that both social and economic values and technical issues associated with historic and cultural identity in the built environment could be expected to be a source of some resistance to retrofit. There appear to be opportunities to combine strategies for retrofit of historic areas with evaluation of the maintenance needs and options for historic and conservation stock. This could also be reflected in discussion of the energy futures of heritage landscapes. Indeed, the participatory methodologies that are highlighted by the retrofit literature have tended to be more strongly developed in rural planning and development research and this could prove a valuable interaction.

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Review 2: Behaviour Change and Energy Transitions – Implications for Retrofitting

Introduction

This review is based on the perception that a shift towards more sustainable forms of energy consumption and production will necessitate behaviour change by individuals. Drawing on work related to 'pro-environmental' behaviour, it examines some of the perceived drivers of individual behaviour change. A number of empirical studies, which examine the effectiveness of efforts to put behaviour change into practice, are highlighted. It then goes on to explore the governance implications of the concept that energy use behaviour both produces and is produced by socio-technical systems.

Individuals and households account for almost half of current UK carbon emissions, with household energy use (including private car use) accounting for 42% of the total (Defra, 2008). However, there is an apparent disconnect between the increasing awareness of the need to reduce the use of energy based on non-renewable resources and an increase in aggregate household energy consumption (Christie, Donn, & Walton, 2011; Vale & Vale, 2010). This has led researchers to examine why energy consumption is continuing to rise, despite developments in household efficiency measures and advances in the energy efficiency of household materials, technologies and appliances available. They have drawn attention to a number of contributing factors.

Firstly, despite the increased availability of energy efficiency measures, and the apparent financial and environmental benefit in investing in such measures, they are not being adopted at the expected rate (Christie, Donn, & Walton, 2011; Gram-Hanssen et. al., 2007; Crosbie & Baker, 2010). Moreover, while household energy efficiency has risen, this rise in efficiency can be negated by poor use of energy efficiency measures (Gill, et. al., 2010) or can be offset by a number of factors including, for example: an increase in the number of appliances in the home (Vale & Vale, 2010), increases in the temperature to which houses are heated at (Lomas, 2010) or increases in the floor area of the house (Summerfield, et. al., 2010). The phenomenon of increased efficiency being offset by increases in energy consumption has been termed the 'rebound', or 'take back' effect. This suggests that household energy efficiency measures can encourage more profligate use of energy because energy users feel they do not have to be as 'miserly' with energy usage (Jenkins, 2010; Greening, Greene & Difiglio, 2000). For example, a review study of the rebound effect found that the instalment of an efficient washing machine correlated with an increase in the amount of washing done (Sorrel, Dimitropoulos & Summerville, 2009).

In this context there have been arguments that reducing energy demand is not simply about developing energy efficiency measures and technologies. Rather, emphasis also needs to be placed on changing behaviour (Vale & Vale, 2010) – not only in regard to purchasing behaviour (e.g. buying efficient products), but in relation to the everyday usage of energy. Indeed, a recent study found that in specially designed low energy buildings, the behaviour of the household affected both heating and electrical energy consumption significantly (Gill et. al., 2010).

These calls for a focus on household behaviour seem congruent with a broader understanding that a substantial reduction in emissions will require shifts in people's behaviour. Indeed, Lord Stern (Stern, 2007: p. 395) argues that:

> "In the case of climate change, individual preferences play a particularly important role. Dangerous climate change cannot be avoided through high level international agreements; it will take behavioural change by individuals and communities, particularly in relation to their housing, transport and food consumption decisions"

In this context, Owens & Driffill (2008) argue that a commonly held assumption is that changes in individual behaviour can achieve "a step change in energy efficiency", and secure a sustainable energy supply for the future. This assumption can be seen within UK government approaches. Parag and Darby (2009) suggest that in the UK policy context, behavioural change by individuals and households is understood to be key in reducing the amount of energy consumed and thus emissions from energy consumption. This behavioural change relates to consumer purchasing – i.e. individuals modifying their purchasing behaviour towards energy efficient, low- and zero-carbon technologies and goods, as well as changes to individual's "routine behaviour" – e.g. running a washing machine at 30 degrees centigrade, or switching all appliances off completely rather than leaving them on standby (DECC, 2009). Indeed, it is argued that government sees changes in individual behaviour as central in 'pulling' society towards lower-carbon energy systems and the development of alternatives to carbon intensive forms of living (Parag & Darby, 2009: p. 3985). In this context, steering society towards more sustainable energy usage and systems revolves around helping and encouraging people and households to change their behaviour towards "the right choices" (Decc / Defra, 2009).

Theories of Environmental Behaviour

This section examines the current understandings about behaviour and its drivers. Microeconomic theories of behaviour are based on the assumption that individuals will want to maximise utility (benefit) at the least cost, i.e. individuals are essentially self-interested and instrumental. Within this model access to information is crucial, as it is only through information provision that actors are able to make the optimal decision in terms of costs and benefits. In the context of energy such a model suggests that individuals will reduce energy use or invest in energy efficient / zero-carbon forms of energy if they possess the requisite information and it is in their (financial) self interest to do so (e.g. benefits outweigh costs) (Wilson & Dowlatabadi, 2007; Jackson, 2005). However, it is argued that energy-efficiency technologies are not being adopted at the expected rate despite the fact that they not only reduce environmental problems but also increase social and economic wellbeing as well as increase utility in terms of health, comfort and productivity (Christie, Donn & Walton, 2011).

Behavioural models

Microeconomic rational choice models have both been critiqued and elaborated on by drawing on notions of framing (utility / preference is depended on a reference point[1]), variable future discount rates (the value of costs and benefits change in a non-linear fashion over time), various forms of heuristic (or habit) and emotion (Wilson & Dowlatabadi, 2007, p. 174-175; Jackson, 2005: p. 35-37). However, there are another set of theories which similarly rest upon the assumption that individual actors are 'rational'. At the core of these theories is the notion of 'attitudes'. In such theories, a behaviour is understood to be preceded by an attitude towards that behaviour. This attitude is in turn informed by an evaluation of the characteristics of that behaviour (Jackson, 2005). For example, the attitude towards purchasing / installing a low energy light bulb might be based upon an evaluation of its environmental impact, money saving potential, its aesthetic qualities, the quality of the light and so on (see for example: Crosbie & Baker, 2010). The assumption underlying this model is that attitudes towards a behaviour can be modified primarily through education and information provision (Stern, 2000; Hargeaves, 2008).

In a widely referenced model – Ajzen's (1991) Theory of Planned Behaviour – attitudes and *perceived behavioural control* (PBC) are understood to be factors which interact with behavioural intention and actual behaviour. PBC relates to the *perception* of the ease or difficulty with which an individual can undertake a behaviour (Turaga, Howarth & Borsuk, 2010: p. 216). The notion of PBC shares similarity with the notion of 'self-efficacy'. Self-efficacy is defined as "how well one can execute a course of action required to deal with prospective situations" (Jackson, 2005: p. 49). The implicit assumption within both notions of PCB and self-efficacy is that if a behaviour is understood to be impossible it will not be undertaken, "despite the motivation being present" (Darnton, 2008: 19). However, it is suggested that encouragement and "emotional arousal" can increase feelings of efficacy (Darnton, 2008: 20). Moreover, feelings of self-efficacy can be strengthened through feedback in response to the performance of a behaviour (Grohoj & Thogersen, 2011), although negative feedback may deter those who have low perceptions of self-efficacy from further action. Wilson & Dowlatabadi (2007) argue that it is crucial for interventions

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[1] See Lindenberg & Steg, (2007) for a theory of goal framing and environmental behaviours (see also: Spence & Pigeon, 2010).

to enhance an individual's perceptions of self-efficacy through education and training as well as feedback mechanisms.

A number of studies also draw on the concept of *values* (Stern, 2000; Barr, 2003; Gilg, Barr & Ford, 2005; Turaga, Howarth & Borsuk, 2010). Values are understood to be higher level psychological constructs than attitudes or beliefs (Jackson, 2005). It is suggested that individuals hold general values that can be placed on continua ranging from 'egoistic' to 'altruistic', from 'conservative' to 'open to change', and from 'bio-centric' (nature has intrinsic value) to 'anthropocentric' (nature has instrumental rather than intrinsic value) (Barr, 2003: p.229). In Stern's (2000) value-belief-norm model, which focuses on environmental behaviour, such values are linked to beliefs about humans' relationship to nature. In this model, altruistic and bio-centric value orientations are positively correlated to an 'ecological worldview' – which includes concepts such as: nature is in a delicate balance and humans have an ability to upset that balance and there are limits to the growth of human societies (Turaga, Howarth & Borsuk, 2010). Acceptance of this 'ecological worldview' is positively associated with awareness that certain conditions pose a threat to the things an individual values (e.g. the environment) as well as an awareness that actions an individual could take could avert that threat (Stern, 2000). This in turn leads to the activation of a *personal norm*, or a sense of moral obligation to engage in certain behaviours, which consequently correlates with actual performance of the behaviour. In contrast to those who hold altruistic or bio-centric values, studies using this model have found that egoistic values correlate negatively to activation of feelings of responsibility to the environment (Stern, 2000).

Hargreaves (2008) argues that within Stern's model there is an understanding that values are social in nature. This, Hargreaves suggests, is a crucial advance in understanding, as such a conceptualisation moves away from a notion that behaviours are linked to individualised cognitive structures and processes. With values understood as social constructs the emphasis is placed upon steering the normative basis of society towards more altruistic / environmentally friendly values (Jackson 2009). How could such steering take place? While a focus on values appears to move away from a concern with individual cognitive structures and processes, suggestions relating to the changing of values nevertheless still seem to rely on information and educational approaches; albeit aimed at "moral suasion/education" (Wilson & Dowlatabadi, 2007: p. 185; see also Stern, 2000: p.419). However, while two studies by Barr and colleagues (Barr, 2003; Gilg, Barr & Ford, 2005) back up the suggestion that more altruistic and bio-centric values are linked to pro-environmental behaviours, they argue that "values are not easily manipulated" (Gilg, Barr & Ford, 2005: p. 499). Moreover, while bio-centric values were found to be positively correlated with environmental behaviour, both studies found that there were a great many other factors which combine to determine behaviour. The following examines a number of other factors that have been theorised to influence behaviour.

A number of models stress the importance of *norms* as determinants of behaviour. In Ajzen's (1991) Theory of Planned Behaviour a person's *subjective* norm is understood as an important determinant of behaviour. A subjective norm is the perception of what (important) others think about a particular behaviour (Jackson, 2005: p.46-47). The implicit assumption in such a model is that if an individual perceives that others will see the behaviour positively, then the individual is more likely to perform that behaviour. This understanding of the norm appears to be different to that of *personal norms*. Personal norms are understood to be anchored in the self, and hence feelings of moral obligation to engage in certain behaviours are conceptualised as an individual phenomenon. However, *subjective* norms are more closely related to one's social context – and hence are anchored in one's social group (Harland, Staats & Wilke, 1999).

A social norm refers to what is perceived to be normal in a given circumstance. It is suggested that if people feel that a certain behaviour is normal in a given context, they will tend to copy that behaviour. Such social norms (Evans, 2007) have been understood as drivers for pro-environmental behaviours. Hence, one is likely to engage in 'green' behaviours if one is a member of a group in which such behaviour is normal (Dono, Webb & Richardson, 2010). Or, if composting is perceived to be the norm others who are not composting will begin to do so (McKenzie-Mohr, 2000). Norms, then, relate to the 'appropriate' forms of behaviour in a given circumstance. In this regard they can be connected to social sanctions and rewards. Those who behave in ways that are consistent with what is normal in a given circumstance may experience social approval – while behaviour in contrast to the norm may be met with disapproval and other sanctions (Jackson, 2005: p. 60). This may explain why norms have been found to change behaviour (De Young, 2000) but equally it may explain why people do not change their behaviour to pro-environmental forms. Indeed, Lorenzoni, Nicholson-Cole & Whitmarsh (2007) argue that a significant barrier to adopting pro-environmental behaviour is the perception that the majority of other people do not undertake pro-environmental behaviour and that such 'green' forms of behaviour are 'weird' and undesirable.

Contextual Factors

Stern (2000) argues that further factors that contribute to pro-environmental behaviour can be understood as 'contextual'. What constitutes 'contextual factors', however, is rather broad and heterogeneous. Stern (2000: p. 417) suggests that contextual factors can include:

> "interpersonal influences (e.g. persuasion modelling); community expectations; advertising; government regulations; other legal and institutional factors (e.g. contract restrictions on occupants of rental housing); monetary incentives and costs; the physical difficulty of specific actions; capabilities and constraints provided by technology and the built environment (e.g. building design, availability of bicycle paths,

> solar energy technology); the availability of public policies to support behaviour (e.g. curbside recycling programs); and various features of the broad social, economic and political context (e.g. the price of oil, the sensitivity of governments to public and interest group pressures, interest rates in financial markets)"

Barr's study of recycling behaviour, supports the conclusion that both context and attitudes are factors in pro-environmental behaviour, while noting that one contextual factor – access to kerbside recycling – "was of crucial importance" (Barr, 2003: p. 235). However, Shove (2010: p. 1275) argues that as more factors are added to such models "the more muddled the picture becomes". Indeed, as more factors are added and the models become more complex, while they offer more robust explanations for certain behaviours, their empirical applicability reduces (Jackson, 2005). Furthermore, there is an underlying tension in such models. In Stern's Attitudes-Behaviours-Context (ABC) model, attitudes and context are both factors in determining behaviour. The reliance on attitudes to explain behaviour suggests that individuals' preferences shape behaviour, while reference to contexts implies that individuals behaviours are shaped by external factors rather than preference (Shove, 2010)[2]. However, it is suggested that if contextual factors are conducive, or not too limiting, for a certain behaviour, then psychological variables will become the main determinant of whether a behaviour is undertaken or not (Wilson & Dowlatabadi, 2007).

Social Marketing

A number of scholars have drawn attention to findings which suggest that individuals can be grouped together on the basis of various factors, including: 'pro-environmental' values, attitudes and behavioural qualities (Gilg, Barr & Ford, 2005; Wilson & Dowlatabadi, 2007; Stern, 2000; Egmond, Jonkers & Kok, 2006). This has led to suggestions that attempts to change behaviour towards more pro-environmental forms should not be based on generic "one size fits all" approaches (Egmond, Jonkers & Kok, 2006: p. 3466). Rather, more differentiated approaches should be adopted which target different 'segments' of the population.

Such an approach can be discerned within *social marketing*. Social marketing employs understandings that were originally developed in the commercial sector. The key difference, however, between social and commercial marketing is found in its aims. While commercial marketing is employed to maximise profit and shareholder value, social marketing aims to achieve a "social good" (Nation Social Marketing Centre for Excellence (NSMCE), 2005). One of the key basic tenets of social

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[2] Barr (2003: 235) highlights that psychological variables (such as attitudes) are not independent of context and in fact affect such factors.

marketing is that the population can be differentiated into groups by any number, form and combination of variables (Giles & Lee, 2008). However, social marketing is understood to go beyond the traditional concerns of demography, and constructs groups on the basis of behavioural and psychological factors (NSMCE, 2005). One adopter of this approach is the Department of the Environment, Food and Rural Affairs (Defra). In 2008, Defra released *A Framework for Pro-Environmental Behaviours* (Defra, 2008) which divided the population into seven "segments", each with their own particular environmental values, attitudes and behavioural factors: 'Positive Greens'; 'Waste Watchers'; 'Concerned Consumers'; 'Sideline Supporters'; 'Cautious Participants'; 'Stalled Starters' and 'Honestly Disengaged'.

Another key tenet of social marketing is that interventions should focus on specific behaviours (NSMCE, 2005). In the case of Defra the specific behaviours targeted can be found under the heading of twelve "headline behaviour goals" (Defra, 2008: p. 27). These behaviours included: 'install insulation products'; 'better energy management and usage' and 'buy energy efficient products'. By mapping the behaviours onto the seven groups, Defra was able to devise a matrix which shows which segments were likely to adopt which behaviours. By further mapping this matrix onto forms of intervention, Defra is able to identify which forms of intervention and messaging are likely to be most applicable to each segment (Defra, 2008).

Corner & Randall (2010) argue that social marketing is a framework for designing behaviour change programmes rather than a change programme in itself. Within this framework emphasis is placed on discerning the 'motivations' and 'barriers' for specific behaviours, for specific groups (McKenzie-Mohr, 2000). Based on this understanding, differentiated forms of intervention can be applied, aimed at overcoming barriers to change or exploiting certain motivations (Coroner & Randall, 2010; Barr, Gilg & Shaw, 2011). In this regard Darnton (2008) argues that social marketing draws on a range of insights from the literature on behaviour. This range of insights has meant attention has been paid to the array of different interventions that may lead to behaviour change. Hence, it is not posited that one form of intervention will suffice, but rather a mixture of interventions, which both target internal (psychological) and external (contextual) factors, will be most effective (NSMCE, 2005: p. 35). Hence, social marketing approaches, such as Defra's, are based on the understanding that different segments of the population may require different forms and mixes of intervention (e.g. regulation, fiscal incentives, infrastructure provision, information and so on) to steer groups towards pro-environmental behaviour (Defra, 2008). However, despite this apparent "what works philosophy" (Coroner & Randall, 2010: p. 2), the emphasis appears to be on communication and information strategies that focus on and attempt to modify the internal determinants of behaviour (Hargreaves, Nye & Burgess, 2008; Frame and Newton, 2007) – albeit with messages that are tailored to the values, beliefs and attitudes of the target audience (Coroner & Randall, 2010).

Empirical Studies on Governance and Energy Behaviours

This section draws on some empirical studies that have examined governance interventions aimed at encouraging energy behaviour change through employing feedback and monitoring mechanisms and community-based action. It will try to draw links with the theoretical understandings of behaviour and its drivers examined in the previous section.

Feedback and Energy Monitors

There has been an increased interest in *feedback* mechanisms to stimulate energy behaviour change. Feedback is understood as "actions taken by (an) external agent(s) to provide information regarding some aspect(s) of one's task performance" (Gronhoj & Thogerson, 2011). In the context of energy, feedback on energy consumption is understood to, firstly, 're-materialise' energy use (Burgess & Nye, 2008). As energy is an abstract force that enters the home and is often embedded in a number of mundane routines, energy use is often invisible. Hence, feedback on energy consumption is understood to make energy usage more visible and understandable (Hargreaves, Nye & Burgess, 2010). Such feedback mechanisms, then, are thought to promote learning (Thaler & Sunstein, 2009: p. 82) as they can improve awareness and basic knowledge of the energy consumption of different appliances and improve understanding of how a change in energy use patterns could reduce energy consumption (Gronhoj & Thogerson, 2011). In other words, feedback mechanisms increase consciousness of the relevance of one's own behaviour in relation to energy consumption (Fischer, 2008). Hence, feedback mechanisms are also theorised to increase a sense of control, or feelings of self-efficacy in relation to energy use (Fischer, 2008: p. 82; van Dam, Bakker & van Hal, 2010: p. 462). However, feedback is understood to lead to a change in energy behaviours if the feedback is given in conjunction with a goal and information on how to save energy. Yet, while Gronhoj & Thogerson (2011) report that energy saving is often most effective in conjunction with information and challenging rather than easy goals, a review of empirical feedback studies by Fischer (2008) finds that feedback alone leads to energy saving.

The content, style and clarity of the feedback has been theorised to impact upon its effectiveness. There seems to be an agreement that feedback should be clear, simple and easy to understand. However, the way in which feedback should be framed is less clear. In most of the studies in Fischer's (2008) review, feedback reports the amount of energy consumed as well as the costs of the energy consumed. However, one study compared the effectiveness of feedback in terms of the cost, energy quantity or environmental impact, and found no difference in energy saving. These findings seem to undermine the argument that pro-environmental behaviour change is rarely stimulated through appeals to protect the environment (Nolan et. al., 2008). Nevertheless Fischer (2008) argues that the content of the feedback and information accompanying the feedback should be tailored to specific audiences (He, Greenberg & Huang, 2010).

Another form in which feedback can be given is normative feedback. Normative feedback compares a household's energy use with the energy use of other households. This is understood to activate a social norm (Fischer, 2008). In regards to normative feedback, again the results are quite ambiguous. Some studies report that such normative feedback stimulates energy saving (Darby, 2010), others report that the effect of normative comparisons is often under-detected (Nolan, et. al., 2008) while others find that none of the studies utilising normative feedback could "demonstrate an effect on consumption" (Fischer, 2008: p.99). While the results are mixed, Fischer suggests that low energy households could actually increase their energy consumption if comparative feedback suggests that their consumption is below the 'norm'.

Darby (2008: p.450) argues that the important aspect of feedback is that those receiving feedback had "new, actionable information on consumption that could be clearly understood". However, feedback can also be categorised on the basis of two distinctions: indirect and direct. Indirect feedback occurs sometime after consumption has taken place (e.g. on a bill), while direct feedback happens immediately at the time of consumption. Such direct feedback has been shown to be more effective at saving energy than indirect feedback (Gronhoj & Thogerson, 2011).

One of the ways direct feedback is possible is through the use of energy monitors. It is argued that energy monitors can improve energy literacy and stimulate interest in the purchasing of energy efficient appliances or renewable energy technologies (Gronhoj & Thogerson, 2011; Hargreaves, Nye & Burgess, 2010). In December 2009, DECC declared that it intended for every household in the UK to have a 'smart meter' accompanied by an energy monitor by 2020. Energy monitors usually use some form of electronic device to display, in various formats, current energy consumption. Currently, most energy monitors only show electricity consumption, but devices which measure gas usage are also possible. Some of the devices allow the user to see aggregate household consumption, or the energy consumption of specific appliances/rooms (van Dam, Bakker & van Hal, 2010).

Research has shown that such devices often produce savings of around 5-15% (Gronhoj & Thogerson, 2011), with the device found to motivate a range of actions, including: turning appliances off, using less, using energy more carefully, improving performance and replacing or using alternative appliances (Darby, 2010). However, recent research suggests the usage of energy monitors often decreases overtime (Hargreaves, Nye & Burgess, 2010) and a recent study has found that energy saving with an energy monitor is not sustained over the medium term (van Dam, Bakker & van Hal, 2010). Furthermore, the use of energy monitors, rather than increasing feelings of self-control, can sometimes lead to a sense of disempowerment as energy monitors can, on occasion, make the challenge of energy saving seem “larger and even more insurmountable” (Hargreaves, Nye & Burgess, 2010: p. 6119). In this regard, Pierce et. al. (2010) argue that energy monitors’ effectiveness and potential counter productive effects should be examined in more detail. Indeed, such an examination as well as ensuring that the social and political context are supportive of changes in energy consumption patterns seems vital “if energy monitors are to realise their potential” (Hargreaves, Nye & Burgess, 2010: p. 6119).

Community Action

Despite Stern (2000) arguing that community based approaches rarely produce much behaviour change on their own, Peters, Fudge & Sinclair (2010: p. 7598) suggest that over the last decade there has been “a growing recognition” that community action is a vital strategy for addressing energy use and climate change. This “growing recognition” appears to have developed in the context of an understanding that community level approaches are able to tap into a variety of mechanisms which could stimulate individual behaviour change (Heiskanen et. al., 2010). Drawing on Middlemiss’s (2008) review of community level approaches to behaviour change, one can discern a number of key mechanisms:

- Deliberation, Learning and Information.

  Communities or groups provide a locus for learning about environmental problems and solutions. They also function as networks of trusted actors through which information and ideas can be exchanged and circulated. Such ‘social learning’ within trusted networks is understood as an “effective tool for encouraging new behaviours” (Sustainable Development Commission & National Consumer Council (SDC/NCC), 2006; also see: Peters & Jackson, 2008: p. 20-21).

- Social Norms

  Community and group level initiatives can lead to the establishment of a ‘green group identity’ and pro-environmental norms of behaviour (Sustainable Development Commission & National Consumer Council (SDC/NCC), 2006; Peters & Jackson, 2008). This can lead to a sense of normative rightness for certain forms of behaviour (Nye & Burgess, 2008).

- Social Support

  Individuals within a community or group can support each other to make changes to their behaviour. Such social support is also understood to dispel the impression that individual actions are taken in isolation (Middlemiss, 2008).

- Individual Gain.

  Group or community activity can lead to individual gain for the individual, including an increased feeling of community or friendship (Middlemiss, 2008).

Despite the apparent applicability of community and group based approaches to changing behaviour, there is somewhat of a paucity of empirical studies relating to community initiatives (Middlemiss, 2008), especially in relation to energy. Indeed, Jackson (2005) argues that despite the clear role of community in mediating and moderating behaviour, what is missing is "proof that community based initiatives can achieve the level of behavioural change necessary" (p. 133). However, a number of recent studies have examined the effects of community-based approaches to changing behaviour. While these community based approaches often do not focus exclusively on energy behaviours, many of them do seek to shift behaviour towards less fossil fuel intensive energy usage.

Studies have noted that community/group initiatives often lead to an increased awareness of environmental issues, the connection of environmental issues to individual lifestyle practices and changes in behaviour (Trier & Maiboroda, 2009; Middlemiss, 2011). Indeed, one community initiative centred on a football club encouraged 3,000 fans to save energy, allowing the football club to claim carbon-neutral status (Baldwin, 2010). However, these studies have not quantified the actual impact of behaviour change, and rely upon self-reported behavioural change.

One of the most well researched group / community approach to behaviour change is the 'Eco-Teams' initiative (see for example: Hobson, 2002; 2003; Staats, Harland & Wilke, 2004; Hargreaves, 2008; 2011; Hargreaves, Nye & Burgess, 2008; Nye & Burgess, 2008). The initiative provides guidance and support in relation to practical actions that people can take to live sustainably. This combination of guidance and support addresses "both behaviour and attitudes simultaneously" (Hobson, 2003: 97), while the communal nature of Eco-Teams has been shown to activate some of the group behaviour change mechanisms highlighted above (Nye & Burgess, 2008).

Participants are asked to weigh or measure particular aspects of their household consumption, for example, weighing rubbish and recycling output or measuring home energy use (Staats, Harland & Wilke, 2004; Hargreaves, Nye & Burgess, 2008; Nye & Burgess, 2008). The process of measuring and feedback within Eco-Teams enables participants to expose taken for granted behaviours to reflexive scrutiny. The feedback also boosts a sense of self-efficacy as it allows participants to gauge, and compare, changes in their environmental impact (Hargeaves, Nye & Burgess, 2008).

The fact that Eco-Teams incorporates a system for measuring the impact of Eco-Team participants during the initiative has allowed researchers to quantify the actual changes that occur. In this regard, studies by Hargreaves, Nye & Burgess (2008) and Staats, Harland & Wilke (2004) found significant changes to household energy consumption attributable to taking part in an Eco-Teams initiative. Moreover, Staats, Harland & Wilke's (2004) longitudinal study found an almost 20% reduction in gas consumption and a 5% reduction in electricity consumption and that changes to behaviour were sustained over the longer term.

However, there have been questions raised as to how far the Eco-Teams initiative engages individuals who are not already 'green' and taking action to cut their environmental impact (Nye & Burgess, 2008). Indeed, studies of community / group initiatives aimed at behaviour change have reported that the groups are often made up of small numbers of committed individuals with limited engagement / apathy from the wider community (Baldwin, 2010; Trier & Maiboroda, 2009; Hoffman & High-Pippert, 2010; Peters & Fudge, 2008).

Critiques of Behaviour Change Models

The review above seems to indicate the importance of many factors in energy behaviours beyond the availability and financial viability of energy efficient technologies, materials and appliances. This suggests that efforts to steer energy behaviours need to take consideration not only of self-interest, but also, values and attitudes towards behaviours, social and personal norms, mechanisms of social support and self-efficacy. However, there has been mounting criticism of many of the behaviour change approaches over the last decade as being overly consumerist / individualistic; primarily focused on information provision and placing 'responsibility' onto the individual while leaving the contextual influences of behaviour under-addressed (Moloney, Horne & Fien, 2010; Gibson, Head, Gill & Wait, 2011; Owens & Driffill, 2008; Fudge & Peters, 2011; Gyberg & Palm, 2009; Lucas, Brooks, Darnton & Jones, 2008; Shove, 2010; Hargreaves, 2011; Butler, 2010; Moisander, Markkula & Eraranta, 2010). Indeed, even social marketing approaches which stress that behavioural change will require different forms and mixes of intervention, which engage both internal and external determinants of behaviour, appear to overly rely upon information provision (Hargreaves, Nye & Burgess, 2008; Webb, 2012) – an argument backed up by a number of studies of social marketing interventions (Frame & Newton, 2007; Haq, et. al., 2008[3]). In this regard behaviour change interventions, despite their increasing sophistication – for example tailoring messages to certain groups, or indeed, the development of community approaches – revolve around informational systems and depend upon individual 'voluntary' self-governance (Paterson & Stripple: 2010; Levy, 2011) [4].

Furthermore, questions emerge as to the nature of behavioural change interventions, and the forms of decision making embedded in them. Some scholars see the dominant behaviour change approaches as a form of one way, top-down messaging (Hargreaves, Nye & Burgess, 2008; Webb, 2012). Hence, it is argued that behaviour change models reflect a form of expert led, technocratic top-down steering of society; rather than an approach which has (democratic) deliberation, participation and co-

[3] Haq, et. al's (2008) study indicated that while a social marketing based initiative seemed to engender some change, the duration of this change was limited.
[4] Indeed it was argued in a recent House of Lords Report that behaviour change approaches have come to represent "alternatives to regulation and fiscal measures" (House of Lords Science and Technology Select Committee (HLSTSC), 2011: 11)

operative strategy-making at its heart (John, Smith & Stoker, 2009). Although Hargreaves, Nye & Burgess (2008: p.753) suggest that forms of behaviour change interventions, like Eco-Teams, can act as "localised deliberative space[s]", these arguments do suggest that behaviour change represents more of a "elite-directed" (Brulle, 2010: 89), top-down approach to the steering of society[5]. The apparent 'top-down' nature of behaviour change and the reliance on information and 'voluntary' self-governance appear to suggest that current behaviour change approaches represent a rather narrow set of governance practices for steering society towards more sustainable forms of energy behaviours.

A number of scholars have argued that individualistic and information based approaches to 'behaviour change' appear to be insufficient to produce the shifts in behaviour required for tackling climate change (Ockwell, Whitmarsh & O'Neil, 2009: p. 307; Lorenzoni, Nicholson-Cole & Whitmarsh, 2007). These authors point to the fact that, despite over a decade of attempts by government and various other actors to encourage changes in energy behaviours through information led approaches, domestic and transport related fossil fuel energy use is in fact rising (Ockwell, Whitmarsh & O'Neil, 2009: p. 307; Lorenzoni, Nicholson-Cole & Whitmarsh, 2007: p. 446). This failure has been linked to a number of factors. Firstly, it is suggested that current interventions focus on "small and insignificant … behavioural changes" (Crompton & Thogersen, 2009: p. 10). Secondly, Whitmarsh, Seyfang & O'Neil (2011) argue that information provision combined with the current lack of a conducive context for behaviour change has led to an increased understanding and awareness of the need to take action, but an inability/unwillingness to do so (this is termed the so called value-action / attitude-behaviour gap) (see also: Ockwell, Whitmarsh & O'Neil, 2009). In this regard it is argued that in order to change behaviour towards more sustainable forms, a "more holistic systems approach" is needed (Lucas, Brooks, Darnton & Jones, 2008: p. 465). The following section examines one particular systems approach: socio-technical transitions.

Behaviour and Socio-technical Transitions

Heilscher, Seyfang & Smith (2011) argue that research has shown that behaviours are not "mainly" shaped by the individual, but rather by context – the socio-technical systems in which individuals live (p. 9-10). In this conceptualisation, certain

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[5] Berg (2011) argues that government is outsourcing environmental governance responsibility to NGO's. This could be understood as a form of de-centred governance, whereby governance for sustainability is being undertaken by actors outside government. Recently, however, a prominent NGO which had been involved in some state environmental programmes argued that "government has tended to view community sector networks as conduits for [government] behavioural change messages and a 'soft' vehicle for the delivery of national policy" (Hand, 2011). This hardly suggests de-centred co-governance.

consumption patterns reproduce, and are the outcome of, an energy system that has evolved over a number of decades (Geels, 2005). The current system is characterised by fossil fuel dependent, centralised and large scale power technologies (Bergman & Eyre, 2011; Foxon, Hammond & Pearson, 2010). The understanding central to this conceptualisation is that if energy consumption and production patterns are to change to more sustainable forms, then there needs to be systemic change. A number of scholars have drawn on and developed multi-level transition theory to understand such systemic change. The following section briefly elaborates on transition theory. It is not the intent to offer an in-depth description of transition theory but rather to outline an alternative view on energy behaviour – a view that seems to be gaining attention.

Niches, Regimes and Landscapes

One way in which to understand how a systemic change is possible is by drawing on a multi-level perspective (Nye, Whitmarsh & Foxon, 2010: p. 698). The first of these 'levels' is the socio-technical landscape. The landscape consists of broad socio-political values and ideologies, macro-economic patterns, demographic trends and materials (including the spatial layout of cities, highways and electricity grids) (Geels, 2011; Geels, 2005). Situated within this landscape are regimes. A regime can be conceptualised as a stable conglomeration of interlocking sets of technologies, institutional practices, rules, norms and behaviours (Verbong & Geels, 2007; Geels, 2005; Foxon, Hammond & Pearson, 2010; Bergman & Eyre, 2011). Here behaviour is but one element of a regime, which is both the outcome of, and reproduces, that regime (Bergman & Eyre, 2011). The final level is that of the *niche*. Niches are understood as spaces in which new radical conglomerations of technologies, behaviours and other social factors, which deviate from the incumbent regime, can develop and evolve (Foxon, Hammond & Pearson, 2010: Geels, 2005; Geels, 2011). Niches represent seeds for radical, new ways of doing things that could, if up-scaled, lead to systemic change. However, a radical shift at the regime level is difficult because socio-technical regimes are often characterised by path dependency and lock-in. Often if changes do occur within regimes, they are incremental rather than whole scale (Verbong & Geels, 2007: Geels, 2011). Nevertheless, windows can emerge for change of the incumbent regime when changes at the landscape level put pressure on the regime or when the existing regime is beset by increasing internal problems and starts to de-stabilise (Geels, 2005).

Governance of Socio-Technical Transitions

Within the literature relating to the multi-level perspective there is an understanding that there needs to be a transition from the current fossil fuel intensive energy regime to one which is 'low carbon' (Scrase & Smith, 2009). A transition from one regime to another is understood to be unpredictable as transitions are non-linear, evolutionary and with multiple causal mechanisms. This suggests that a transition cannot be controlled "in an absolute sense" (Meadowcroft, 2005: p. 484). However, it is argued, transitions can be steered through deliberate governance interventions. A number of authors have suggested key features relating to the governance of transitions:

- Deliberative Spaces and Decision Making

  As socio-technical regimes are produced and reproduced by networks of state, civil society and market actors, governance of transitions need to involve a multitude of actors (Smith, Stirling & Berkhout, 2005). This is especially true in the current deregulated energy regime which is made up of a multitude of state, quasi-state and market actors (for example: DECC, Ofgem, energy companies) (Fudge, Peters, Mulugetta & Jackson, 2011). In this regard one of the key concepts in transition governance is the 'transition arena'. A transition arena is a space in which members of a particular regime or sector can interact and deliberate. While drawing a variety of actors into a transition arena hints at wide ranging participation, the transition literature suggests that these arenas should involve a relatively "small network" which potentially suggests a rather 'elitist approach' (Scrase & Smith, 2009).

- Visions

  A further core part of transition governance is the building of goals and visions amongst a multitude of actors / knowledges within transition arenas. For example a goal could be "make the electricity supply more sustainable" (Scrase & Smith, 2009), with visions representing particular ideas of how these goals could be achieved (Meadowcroft, 2005). Foxon, Hammond & Pearson (2010) suggest that one of the ways these visions could be built is through the development of various transition scenarios between multiple actors. However, visions are understood in the plural, recognising the uncertainty inherent within any transition and seeking to avoid premature 'lock –in' (Meadowcroft, 2005; Smith & Stirling, 2007).

- Regime Shift and Niche Development

  The governance of an energy transition would be aimed at both improvement and innovation. Within this a 'basket' of different interventions is developed including measures which encourage and protect a portfolio of different niche-based innovative bundles of technologies and practices (Meadowcroft, 2005; Scrase & Smith, 2009).

- Feedback, Learning and Adaptation

  Central to transition governance is feedback and learning from different forms of strategy. Here goals and visions can be modulated and re-assessed, approaches modified and adapted in light of developments (Voβ & Kemp, 2007). However, this learning involves multiple forms of knowledge and framing – it is pluralistically reflexive – and leads to multiple (re)visions (Smith & Stirling, 2007).

- Role of the State

  Transition governance does not rely on the institutionalised hierarchies of the state – but rather takes place in networks of actors. However, this does not mean that the state has no role. Indeed, state led regulatory and fiscal measures can play a role in transition governance (Meadowcroft, 2007; 2005; Scrase & Smith, 2009). Moreover, the state is often assigned a central role in the building and setting up of transition arenas and as a moderator and supervisor of transition learning and adaptation (Voβ et. al., 2007). In this sense the state is understood to both steer a transition and to facilitate the development of procedures that mobilise and engage various actors (Hendrick & Grin, 2007).

Transitions to Sustainable Energy

There has been criticism of the transition approach due to its perceived tendency to focus on the technical elements of transition and a lack of consideration of patterns of living, consumption and lifestyles (Nye, Whitmarsh & Foxon, 2010: p. 698; Heilscher, Seyfang & Smith, 2011). Despite this lack, Seyfang, Haxeltine, Hargeaves & Longhurst (2010) argue a transition approach highlights the need for significant changes in, and the co-evolution of, energy technologies and infrastructures as well as institutional practices and individual lifestyles. This need for systemic change implied in transition theory is, it is argued, missing from "models which focus on behaviour change at the individual level" (Seyfang, Haxeltine, Hargeaves & Longhurst, 2010: p.4). However, rather than dismiss individual models of behaviour change, Nye, Whitmarsh & Foxon (2010) argue that a fruitful approach would be to integrate psychological / socio-psychological understandings of behaviour into transition theory, thereby overcoming the perceived tendency to focus on technical elements of transition and also combining advances in both fields. Such an integrative approach, it is suggested, would allow an examination of how domestic actors could play an active role in a move towards a low energy system, while highlighting the need for more systemic changes (Nye, Whitmarsh & Foxon, 2010; Seyfang, Haxeltine, Hargeaves & Longhurst, 2010). In this regard an integrative approach would explicitly address the relationship between 'push' and 'pull' factors needed in a shift to a more sustainable energy system (Heilscher, Seyfang & Smith, 2011; Smith & Kern, 2009).

Decentralised Energy Systems, Experiments and Behaviour

One of the core tenets of a transition approach is that a transition in the current energy regime could come about through the development and scaling-up of new conglomerations of social and technical elements. A number of studies have examined Dutch attempts to operationalise the understandings of transition governance. These studies have been relatively 'high-level' and have highlighted some of the difficulties in transition governance processes (Kemp, Rothmans & Loorbach, 2007; Hendricks & Grin, 2007; Smith & Kern, 2009). However, Verbong & Geels (2007) also examined Dutch attempts to promote and support decentralised micro-renewable energy production at the niche level.

One of the radical scenarios imagined in the transition literature is the move towards decentralised micro-renewable energy systems (Foxon, Hammond & Pearson, 2010). Such systems are comprised of networks of community / household level micro-renewable energy technologies. There has been little research to date which has examined the development of decentralised energy systems from a transition perspective (although see Walker & Cass, 2007). However, the transition perspective suggests that there needs to be a multitude of experiments with different bundles of technologies and institutional and social practices supported at a multitude of levels (Geels, 2011). Indeed, a number of studies on localised renewable energy have highlighted the need to explore different types of:

- Financial support
  Feed-in-tariffs, low cost loans for renewables and initial help with capital investment can increase the economic viability of household or community renewables (Saunders, Gross & Wade, 2012; Walker 2008)

- Ownership / management and operation
  There are a number of different ownership models for localised renewable systems. These can comprise of local co-operative / charity models, development trusts, share holding, private ownership or pay-as-you-generate models (Walker, 2008; Saunders, Gross & Wade, 2012).

- Technology
  Different forms of micro-renewables are available including: wind, biomass, solar PV/thermal, hydro and heat pumps. Not only would different forms and combinations of these technologies need to be explored but also how they are connected and networked (Walker & Cass, 2007).

- Regulation / Planning
  While planning regulations for micro-renewables have been relaxed, Williams (2010) suggests that planning institutions at the national and local levels needs to explore different planning practices to encourage decentralised renewable energy production.

- Supply Chains and Information
  A distrust of installers, poor performance of technologies and a lack of supply have been suggested to be barriers to the installation of a number of

sustainable technologies (Crosbie & Baker, 2009). This suggests the need for the development of supply chains, training, re-skilling and the development of knowledge sharing practices (Bergman & Eyre, 2011).

- User behaviour

  Different forms of user behaviour will be needed to be explored and developed in conjunction with new energy technologies so that they are effective (Bergman & Eyre, 2011). This may involve new combinations of technologies and individual and social activities – new practices of washing and cleaning, entertainment and so on (Shove & Walker, 2007; Shove & Walker, 2010).

A move towards a decentralised energy system may help towards the binding European Council target of 20% of renewable energy by 2020 (Walker & Cass, 2007). However, the list above highlights the complicated set of factors and actors that need to coalesce for the development of such a decentralised system (see: Walker et. al., 2007). These factors might include subsidies and fiscal support, changes in planning practices, technology development, mechanisms for training and knowledge sharing, new user behaviour as well as the development of models of renewable ownership and management. This seems congruent with an understanding that seeds for a sustainable energy regime may come from new conglomerations of a whole host of elements. This list also suggests multiple governance mechanisms are needed to bring these factors into alignment (Geels, 2011: p.25).

Walker et. al. (2007) argue that there has been increasing policy emphasis on finding ways to support localised and distributed patterns of energy production (see also: Walker & Devine-Wright, 2008). Indeed, Bergman & Eyre (2011) suggest that the recent Decc funded Low Carbon Communities Challenge (LCCC) programme could be seen as an example of how government is making conscious efforts to institutionally and financially support new localised niche experiments in different forms of decentralised energy production. The LCCC awarded between £400,000 and £500,000 to community groups who were seeking to reduce carbon emissions at a community level. The LCCC focused on projects that sought to deliver a range of different integrative technological packages through a number of stakeholders[6]. Alongside these integrated technological packages, the projects also included a number of behaviour change interventions (Decc, 2011).

One example of a LCCC project was Transition Streets, which installed a community solar PV system on a civic hall as well as household solar PV systems. The project also included a 'behaviour change' initiative based on the Eco-Teams model within the local community. The Transition Streets project included a number of actors, the local council, the Energy Saving Trust and worked closely with a local installer. While not

[6] See also Bunt & Harris (2010) for a similar approach from NESTA.

independently verified, the report from the project argued that there had been significant reductions in emissions from this project (average saving was 1.3 tonnes of CO2 per household / per annum) (Ward, Porter & Popham, 2011). In this regard, the LCCC and the Transitions Streets project perhaps show the need to experiment with different integrative technological and behavioural packages. However, the LCCC also shows the play between the 'top down' and the 'bottom up'. Indeed, while a community initiative like Transition Streets could be understood as 'bottom up', the state intervention to support and stimulate these community renewable initiatives could be seen as 'top-down' (Meadowcroft, 2005: p. 488). As Ward, Porter & Popham (2011) highlight in their report, the LCCC funding and the feed-in-tariff – a central government policy – was central to the success of Transition Streets. This perhaps highlights the need for 'top-down' government support as well as 'bottom up' efforts in moves towards sustainable forms of energy.

Conclusions

A focus on socio-technical systems suggests that a progression towards more sustainable forms of energy usage / production will require "more than a shift in the attitudes and intentions of individuals" (Walker & Cass, 2007: p. 467). This implies that attempts to steer society towards sustainable energy systems will need to go beyond a focus on influencing individual behaviour. Indeed, Shove (2010) argues that moves towards sustainability will require a radical re-working and re-alignment of "technologies, routines, forms of know how, markets and expectations" (p.1278). Such a shift is beyond the control of one set of actors and will require multiple governance actors. The perceived need for systemic change however, does not mean that psychological/socio-psychological models of behaviour need to be abandoned. Indeed, as this review highlights, there could be a fruitful dialogue between a systems approach and models of behaviour. An integrative approach would suggest that governance for sustainable energy would necessitate a focus on individual 'lifestyles' and behaviour as well as institutional practices, technological development and systems of provision.

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Review 3: Retrofitting and justice

Introduction

This review discusses the justice implications of government-led retrofitting initiatives in the UK over the last fifteen years. It is based on a range of academic and grey literature, including journal articles, books, conference papers, government reports, policy documents and publications from various interest groups. For the purpose of clarification, in this context "retrofitting" covers modifications or refurbishments to existing properties, infrastructure and their surroundings that are intended to achieve sustainability objectives, such as climate change mitigation and adaptation. In particular it seeks to identify what is known about who benefits most from central and local government initiatives for retrofitting the built environment. It aims to identify the scope of relevant policies and programmes, and their interconnections, and what research has been carried out around this question.

The concept of 'justice' is often interpreted in terms of *distribution* (the extent to which burdens and benefits are shared) and/or *procedure* (the extent to which stakeholders are able to contribute to decision-making – see Folger and Konovsky (1989) and Bulkeley and Fuller (2012) for more detailed discussion). Deutsch (1975) provides a useful analysis of three different perspectives on what constitutes a 'just' distribution: one in which individuals receive outcomes that are proportionate to their inputs (known as 'equity'); one that treats everyone as equals ('equality'); and a third that aims to share resources according to need ('welfare'). The definition of 'resources' here can be extremely broad, and indeed an academic literature focusing on the theme of *environmental* justice, which addresses the distribution of environmental impacts, goods and services within and between generations, and between people and the natural world, has developed in its own right over recent years (Davoudi and Brooks 2012).

This review largely focuses on whether the benefits of government initiatives to stimulate retrofitting activity have been distributed according to need. It also comments on procedural issues, such as the level of involvement in decision-making of those individuals or community groups that are affected by retrofitting activity.

Scope of Government Retrofitting Policies and Programmes

Fuel Poverty

Fifteen years ago, the main policy driver for retrofitting activity was the desire to tackle 'fuel poverty' by improving the thermal efficiency of housing. A household was defined as being in fuel poverty if it needed to spend over 10% of its income on fuel to heat its home to an "adequate standard of warmth". This "adequate standard" is generally defined as 21°C in the living room and 18°C in other occupied rooms

(National Audit Office 2003). During the 2000s the Government introduced a plethora of initiatives to attempt to combat the problem, many of which are outlined in detail below. However, the literature suggests that it has had limited success in achieving this objective, partly due to wildly fluctuating energy prices (Hills 2012). In his official review of the Government's strategy, Professor John Hills argued that the way in which fuel poverty is calculated meant that the number of households who fall into this category has varied significantly over the last decade. For example, people who were relatively wealthy but for various reasons spent a lot of money on energy were sometimes classed as fuel poor (Hills 2012). As a result, Hills has proposed an alternative definition, which incorporates an assessment of both income levels and energy costs, and therefore includes those households that:

- have required fuel costs that are above the median level; and
- would be left with a residual income below the official poverty line if they spent that amount on fuel.

Hills' definition also enables the Government to calculate how much additional income these households would require in order to bring them out of fuel poverty. By aggregating these figures across the country, Hills is able to calculate the 'depth' of the problem (what he terms the 'fuel poverty gap') and identify how much extra money is required to ensure that all homes can be heated to the adequate standard of warmth. In 2009 this figure was £1.1 billion, but it is projected to rise to £1.7 billion by 2016. Ninety per cent of this is attributable to households with low incomes who are also living in homes that have energy ratings of E, F and G – therefore those that are least thermally efficient (Hills 2012).

Hills' report, along with analyses by Sefton (2004), the National Audit Office (2009) and Boardman (2012), found that Government policies have resulted in millions of homes undergoing retrofits to various degrees. However, these initiatives have not contributed towards taking a significant proportion of the population out of fuel poverty, regardless of whether the old calculation or Hills' revised definition is applied.

Carbon emissions

In the meantime, the level of carbon dioxide emissions from homes became an increasingly important issue. This has provided a more explicitly environmental reason for the Government to introduce policies that encourage other retrofitting initiatives, such as giving householders and businesses financial incentives to generate their own electricity and heat. Alongside these national policies there have also been a growing number of 'bottom-up' initiatives that seek to retrofit residential areas – at both the neighbourhood and wider district levels (see Bird and Lawton 2009 or Bulkeley and Fuller 2012 for some examples). In many cases these have addressed much broader sustainability issues, rather than focusing narrowly on reducing carbon emissions. Despite these projects however, the overwhelming focus of government policy has been to improve the energy efficiency of homes, rather than retrofitting localities, infrastructure or non-domestic property. This is in spite of the potential benefits of taking a more holistic approach (Sustainable Development Commission 2010).

In addition, although various government retrofitting initiatives have improved the quality of life of millions of citizens, they have had limited impact on carbon emissions because they have tried to target people who use relatively small amounts of fuel. It is generally the case that "the highest earning households use the most energy, emit the most carbon dioxide, [and] occupy the majority of untreated housing stock as well as a disproportionately high percentage of the residual 'easy to treat' homes" (Ashby and Pitts 2012, 1). Indeed, various studies have found a positive correlation between income and residential energy consumption (Summerfield *et al* 2010). For example, Druckman *et al.* (2008) calculated that the highest earning 10% of the population spent 2.3 times as much on domestic fuel as the lowest earning decile in 2004, and Utley (2008) also found this to be the case four years later. This raises a significant issue: retrofitting policies that target specific households who are in need may be laudable in distributive justice terms, but they might not necessarily represent the most effective way of reducing carbon emissions from UK homes. At the same time, the 'rebound effect' sees households heat their homes to a higher temperature after thermal efficiency measures have been installed, in the knowledge that their bills will not rise significantly. Calculations of the size of this effect appear to vary considerably (Haas and Biermayr 2000; Berkhout *et al* 2000; Clinch and Healy 2003; Meijer *et al* 2009; Guerra Santin 2011; Jenkins 2010; Chahal *et al* 2012). However, Sunnika-Blank *at al* (2012) argue that there is up to a 50% difference in energy consumption between the prediction and the reality in a retrofit, meaning that it is a significant factor to consider in future policy-making.

Furthermore, as the UK Green Building Council (2008) and Boardman (2012) have pointed out, the extent of retrofitting that will be necessary to deliver carbon reductions of the level required will cost more and have a longer payback period than installing basic loft and cavity-wall insulation, or low-energy lighting. It remains to be seen whether the coalition Government's proposed Green Deal (which is discussed later in this review) will be sufficiently attractive to encourage enough households to fund these higher-cost solutions.

Other Sustainability Objectives

While other sustainability objectives for retrofit are embraced by householders and residential landlords as part of refurbishment activity, there are few examples of these being directly supported by government policy or funding (apart from the Decent Homes Initiative, which is discussed later in this paper). Water efficiency is a case in point: the Government's Water Strategy, which was published in 2008, did not set out any specific plans for retrofitting existing homes by supporting the installation of rainfall capture of grey water recycling technologies (DEFRA 2008). Similarly, the Heatwave Plan for England (NHS 2011) calls for government departments, local authorities, the NHS and public health authorities to promote the greening of the built environment, shading and insulating buildings, with specific recommendations for hospitals estates and care homes. However, it is does not set out explicit programmes to ensure that this will be achieved.

In addition to the perceived social and environmental benefits of retrofitting, another driver for these policies has been the creation of new businesses and jobs. Yet in spite of the potential economic benefits of developing such 'green collar' industries, there appears to have been little coordination between retrofitting initiatives and the drive to re-configure traditional industries around low-carbon issues – at least within central government. In addition, developments in these two areas have differing implications for distributive justice: thus far, most parts of society have benefited in various ways from property retrofitting initiatives, whereas it is not yet clear how the fruits of a low-carbon economy will be shared.

Energy Retrofit for Single Buildings

Residential Buildings

Western countries have developed a range of policies to try and improve the thermal efficiency of homes over the last forty years (Geller *et al* 2006). Since 1997, the UK Government has introduced numerous initiatives to achieve this objective, beginning with a focus on social housing, before broadening out to 'easier to treat' properties in the owner-occupied sector – those with cavity walls or lofts that are easy to insulate. This made some notable early progress: between 2002 and 2010, Government-backed initiatives had helped to facilitate the installation of some energy-saving measures in 7.5m homes (HM Government 2010a). However, even though retrofitting has continued apace since then, by early 2012 around 40% of lofts and cavity walls had still not been insulated (DECC 2012). Although incentives will still exist for households to get this work done through the Green Deal, the focus has begun to shift towards those older homes that are much more difficult to upgrade. For example, only around 2% of homes with solid walls have been insulated (DECC 2012a), and installing this in a further 7 million properties of this type across the country will be a significant and expensive undertaking.

The extent of the work required to upgrade domestic property reflects the fact that the UK's housing stock is amongst the oldest and least energy-efficient in the world (DECC 2011a). Indeed, in a survey of 26 European countries, Britain was found to have the highest percentage of domestic property that was built before 1945

(Gleeson *et al* 2011). Older properties are much more likely to be energy-inefficient, particularly if they have not been refurbished to improve insulation, since building regulations have become increasingly stringent over recent decades (DCLG 2006b).

In fact, building types in the UK vary enormously from solid walled properties with electric heating and little insulation through to highly thermal efficient homes that generate their own energy (UK Green Building Council 2008). The latter types tend to be properties that have been built more recently, and indeed the Government has stipulated that all new homes in England must be 'zero-carbon' from 2016 (DCLG 2010), and all new non-domestic property must meet this standard by 2019 (DCLG 2009).

Nonetheless, it is widely accepted that the vast majority of buildings that will be in place in 2050 has already been constructed (Boardman 2012). This date is important because it is cited in the Climate Change Act as being the deadline for the UK to reduce its carbon emissions by 80% compared to 1990 levels. Since domestic properties account for 27 per cent of existing emissions (DCLG 2009), it is necessary to improve their thermal efficiency significantly in order to reduce energy demand. Indeed, according to the Department for Energy and Climate Change (DECC 2011a), a significant proportion of these homes would benefit from retrofitting. In social, economic and environmental terms, this solution is much better than demolition and rebuild, because of the resources and processes involved in knocking down old buildings and constructing new ones. A study in the US found that it takes up to 80 years for a new building, that is 30 percent more efficient than an average-performing existing building, to 'overcome' the negative climate change impacts related to the construction process (National Trust for Historic Preservation 2012). Power (2008, 4488) argues that "refurbishment most often makes sense on the basis of time, cost, community impact, prevention of sprawl, reuse of existing infrastructure and protection of existing communities. It can also lead to reduced energy use in buildings in both the short and long term".

Mindful of both this challenge and the objective of reducing fuel poverty, the Government implemented a variety of initiatives that had the explicit objective of improving the thermal efficiency of housing to address fuel poverty. Indeed, the 2000 Warm Homes and Energy Conservation Act placed a legal duty on the Government to do "everything reasonably practical" to eradicate fuel poverty by 2016 (2018 in Wales (Fuel Poverty Charter Wales 2009)). Although Hills (2012) suggested that applying his new definition would mean up to 3 million households will still be in fuel poverty by this date, the UK Government has not (yet) said that it will abandon the pledge. Similarly, parties that have since taken power in Edinburgh, Cardiff and Belfast have also said that they support the objective.

By the end of the 2000s, environmental considerations had become increasingly important, and the Government's Low Carbon Transition Plan (HM Government 2009) set out an aim of cutting emissions from fossil fuels in homes by 29% by 2020. To achieve this, it proposed installing loft and cavity wall insulation into every home by 2015 'where practical', and delivering 'eco-upgrades', which would include advanced retrofitting measures such as solid wall insulation, in up to 7 million homes by 2020 (HM Government 2010a).

The various energy-efficiency schemes were delivered through a combination of government agencies and the energy companies, with both parties contributing around 50% of the funding. In reality, this means the costs have been shared by domestic energy customers and taxpayers – an arrangement that has significant justice implications, as discussed below.

The two main state-funded programmes were Warm Front and the Decent Homes programme. Together they have meant that social housing is more energy-efficient than private rented and owner-occupied property (Gleeson et al 2011; Boardman 2012; DCLG 2012a). However, fuel prices doubled in real terms between 2003 and 2009 (Hills 2012), which has meant that social renters are still more likely to be in fuel poverty compared to owner-occupiers (using the pre-Hills definition of a household that has to spend over 10% of its income on heating their home to a required standard). In addition, as two-thirds of all housing is owner-occupied (DCLG 2012a), there is still a significant challenge ahead to upgrade the remaining private homes – property over which the Government has much less direct control.

Through other schemes, such as the Energy Efficiency Commitment (EEC) and Carbon Emission Reduction Target (CERT) the Government has placed duties on energy providers to encourage customers to reduce unnecessary energy consumption and improve the thermal efficiency of their properties. These initiatives have been funded largely by levies on energy bills rather than taxation, and these surcharges are paid by all customers, regardless of their income. Although lower-income households tend to consume less energy, fuel nonetheless accounts for a greater share of their overall expenditure. As such, they have been asked to shoulder a disproportionately large burden in order to fund these initiatives. In many cases the Government has obliged power companies to ensure that some schemes are targeted at vulnerable groups, and indeed Boardman (2012) found that most of the grants that have been funded by energy suppliers were targeted at the fuel poor. Nevertheless, Hills (2012) calculated that all of the existing initiatives aimed at combating fuel poverty (including those that are not associated with retrofitting or energy efficiency, such as the Winter Fuel Payment and Warm Home Discount Scheme – schemes that provide grants to help vulnerable households pay their heating bills) only had the potential to reduce the fuel poverty 'gap' by one-tenth. As mentioned earlier, this 'gap' indicates the amount of extra money that is required to ensure that all homes can be heated to the adequate standard of warmth.

The main Government programmes to support residential retrofitting, and some of their justice implications, are outlined below (and summarised in Table 3.1).

Table 3.1: Key residential retrofitting initiatives and related justice issues

Initiative	**Key characteristics**	**Justice issues**
Warm Front	Provided subsidised insulation measures to households that are vulnerable to fuel poverty and living in private tenures	Tenants require landlord permission to apply, but no such consideration for owner-occupiers Broadly re-distributive towards people on lower incomes, but many eligible households were not fuel poor. Many homes (such as those without cavity walls or lofts) could benefit from some of the measures on offer
Decent Homes	Upgraded social housing so that it met minimum standards of facilities and thermal efficiency	Limited to social housing. Tenants often not consulted about work done to their homes. Has resulted in this sector becoming significantly more energy-efficient than others
Energy Efficiency Commitment	Obliged energy companies to improve thermal efficiency of homes by offering free/subsidised works.	Funded by a levy on fuel bills and therefore affects lower-income households disproportionately. Many homes (such as those without cavity walls or lofts) cannot benefit from some of the measures on offer. Recipients could choose whether to access the scheme or not
Carbon Emissions Reduction Target	Sets targets for energy companies to reduce domestic emissions	Funded by a levy on fuel bills and therefore affects lower-income households disproportionately. Many homes (such as those without cavity walls or lofts) cannot benefit from some of the measures on offer. Customers can opt-in to the scheme
FITs	Provides guaranteed prices for small-scale generators of electricity	Funded by a levy on fuel bills and therefore affects lower-income households disproportionately. Many technologies that qualify for FITs cannot be installed in all properties (e.g. flats)
Green Deal finance	Allows householders to borrow money to fund domestic retrofitting, calculated so that the	Social housing tenants are excluded, and those in the private rented sector will need landlord approval.

	project will cost less than the financial savings that will accrue (the 'golden rule'). The cost of the solution is repaid through electricity bills	Opt-in, therefore fewer procedural issues compared to some other policies – provided the scheme is sufficiently accessible.
ECO – Carbon Saving Obligation	Grants from energy companies to top up Green Deal finance for projects that do not meet the 'golden rule'	Opt-in, therefore fewer procedural issues, provided the scheme is sufficiently accessible. Will be skewed towards properties with solid walls, which receive larger subsidies than those with cavity walls
ECO – Affordable Warmth Obligation	Energy company grants targeted at vulnerable groups that will top up Green Deal finance for projects that do not meet the 'golden rule'	Opt-in, therefore fewer procedural issues, provided the scheme is sufficiently accessible. Only 25% of funding will be allocated to this part of ECO, which Hills (2012) calculates as insufficient to meet need.
Legal requirement for rented property to be rated E or above	From 2018, all property that is rented for housing or non-domestic purposes will need to have an energy performance certificate rating of E or above	One of the few initiatives that will benefit households in the private rented sector. Most upgrades are likely to take place whilst property is empty, and this will reduce any procedural concerns. Concern that it may take some property out of the market altogether rather than raise standards.
Community Energy Saving Programme	Requirement for energy companies to fund 'whole-house' retrofits for whole designated areas.	Householders can 'opt-in' to the scheme, but few have taken it up – so awareness may be low. Does not take account of household circumstances, and therefore many people can access it who may not need the financial support. Funded by all energy customers and therefore potentially regressive
Renewable Heat Premium Payment	Provides taxpayer-funded vouchers to households who want to invest in renewable heating systems	Vouchers for some technologies are restricted to homes that are not on the mains gas grid, which ensures that some of those in need are targeted. Does not take account of household circumstances, and therefore some households may have received grants that do not need them. Take-up has been low, which suggests problems of awareness or accessibility.

Warm Front

Warm Front was introduced in 2000 to subsidise installing basic insulation measures in private tenure households that might suffer from fuel poverty. Although the scheme only applied in England, similar initiatives were introduced in Scotland (the Energy Assistance Package), Wales (Nest) and Northern Ireland (Warm Homes).

Under the programme, households could qualify for up to £3,500 worth of retrofitting work to improve their heating and insulation. The Government had to adopt a series of proxy criteria to try and ensure that Warm Front would be targeted at the right people. Therefore, those receiving specified benefits and credits, disabled people, the over-60s and young families were given grants, subsidies and logistical assistance to retrofit their homes. Notably, the scheme complemented support to improve domestic energy efficiency with advice on the benefits to which benefits recipients were entitled. As such, it aimed to tackle fuel poverty not only by reducing recipients' energy bills, but also by increasing their income.
Since these households are less likely to be able to afford to install insulation themselves, and more likely to under-heat their homes in order to save money (Hills 2012), it would appear that the benefits of these retrofitting initiatives have been distributed largely according to need. Collins (1986) identified a range of temperature requirements that were necessary for humans to live healthily, and also argued that temperatures should be three degrees warmer in homes that housed the very young and very old, because of their more sedentary lifestyles. Echoing these concerns, Hills (2012) also pointed out that older people, particularly those with long-term health conditions, have higher energy requirements because they have to spend more time at home.

Warm Front sought to target some of these groups, and therefore it could also be argued that the programme is justified on health grounds, since it would help to prevent vulnerable people from developing illnesses such as influenza, heart disease or strokes (National Audit Office 2003). There is a substantial body of literature linking health problems to low indoor temperatures (see for example Liddell and Morris (2010) for an overview of the impact of fuel poverty on the mental and physical health of infants, adolescents and older people). Therefore a welfare interpretation of distributive justice should ensure that those people who are particularly vulnerable to these complaints receive services to prevent them from developing. Indeed, as Collins (1986), Healy (2003) and Radian (2010) have identified, the UK's winter mortality rate is substantially higher than that of other developed countries, in spite of the fact that temperatures in Britain do not fall to levels commonly seen elsewhere in Europe. In particular, Healy identifies an interesting paradox, in that "higher mortality rates are generally found in less severe, milder winter climates where, all else equal, there should be less potential for cold strain and cold related mortality" (Healy 2003, 786). He attributes this in part to poor quality housing, contrasting the thermal efficiency standards of Scandinavian homes with those in the UK, Ireland, Portugal and Greece. Drawing on a large dataset, he has developed an 'increased winter mortality index', which calculates that there are 18% more deaths in Britain in winter compared to other months of the year, whilst the corresponding figure in Finland is just 10% (Healy 2003).

However, in spite of the Government's attempt to target the scheme at those most in need, the National Audit Office (2009) found that Warm Front was not sufficiently focused on vulnerable households. Indeed, nearly three-quarters of the households that qualified for the scheme were not necessarily in fuel poverty, and less that one-fifth of Warm Front recipients had this status before they received a grant, partly because the qualifying criteria did not take account of the thermal requirements of their homes (Sefton 2004). More specifically, "those groups who are most likely to be fuel poor are still substantially under-represented among Warm Front recipients, including single pensioners, occupants of less energy efficient dwellings, and low income households" (Sefton 2004, v). In particular, single pensioners were less likely to apply to the scheme than other types of household, despite the fact that they were more likely to be eligible. Overall therefore, it cannot be said that Warm Front was targeted effectively at those most in need of support.

Nonetheless, it did improve the thermal efficiency of many thousands of homes. The energy efficiency of housing is measured using the Standard Assessment Procedure (SAP), which calculates the heat losses, internal gains, lighting and water heating demand of a property based on factors such as its floor area, volume, orientation, infiltration, opening areas and wall-to-window ratio. By the time Warm Front comes to an end in March 2013, it will have spent around £2.8 billion on improving 2.3 million homes, and resulted in an average SAP improvement of 27 points, from 32 to 59 (Hills 2012).

Decent Homes

The Decent Homes programme stipulated that all social housing providers in England and Northern Ireland (except leasehold and shared ownership properties) would need to meet four quality criteria by 2010. As such, it had an explicit aim of improving the quality of lives of tenants, and therefore overwhelmingly *social*, rather than *environmental* drivers. For example, it stipulated that homes should be equipped with modern bathrooms and modern kitchens, and that all 'key' building components would need to be in a good state of repair (DCLG 2006a). Housing is a devolved policy, and the Scottish Government initiated a similar policy (the Scottish Housing Quality Standard), as did the Welsh Assembly Government (the Welsh Housing Quality Standard).

Each of the devolved administrations stipulated that homes should provide "a reasonable degree of thermal comfort". In England this was defined as having both effective insulation and efficient, programmable heating systems. This has resulted in significant public investment in social housing over the course of the last decade. In 2001, the UK Government estimated that there were 1.6m non-decent social homes, of which 1.2m were in the local authority sector. This represented 39 per cent of all social housing (DCLG 2011). The average SAP rating of these properties increased from 50 in 2001 to 60 in 2009, making it significantly higher than the average of 53 for all types of housing (DECC 2011; Hills 2012).

However, the Decent Homes policy raises a number of procedural justice issues, not least regarding the input of tenants into decision-making. As Bennington *et al* (2011) point out, English local authorities were presented with four options for funding the upgrade:

- Transferring their stock to a registered social landlord, which required the support of tenants in a ballot (170 councils took this option);
- Retaining control of their stock and funding it from their own resources (112);
- Establishing an arm's length management organisation (66);
- Raising money through the Private Finance Initiative (14).

Since councils could only transfer their stock with the support of a majority of tenants, this suggests that residents were involved in deciding how their homes would be managed in future. However, they were not involved in the initial decision about the definition of a decent home (which some, including Bennington *et al* (2011) have suggested was too modest), and neither were they consulted about the other funding options. Some of those councils that funded their own improvements did so through a combination of selling assets, prudential borrowing and government grants (see for example Royal Borough of Greenwich 2011). The Government has announced that it would make an additional £2.1 billion available to local authorities and housing associations to ensure that half of the remaining non-decent homes would meet the standard by 2014-15, but changes in the financing arrangements for council homes will mean that any other upgrades will need to be funded internally (DCLG 2011). However, it is unclear as to whether tenants have paid for any of the programme indirectly through higher rents: no literature was found that covers this topic.

Moreover, with the exception of a number of 'exemplar projects' that sought to improve the energy efficiency of some council homes significantly (see for example Bell and Lowe 2000; Sunnika-Blank *et al* 2012), these retrofits were largely done on the assumption that tenants would want the work to be undertaken. Although in most cases the improvements would have been largely unobtrusive, the decision to go ahead with them was nonetheless taken by landlords – not the people who actually lived in the property and who would therefore be directly affected by it. There is an undoubted 'hassle factor' associated with having work undertaken in their homes (DECC 2011a), as well as an identifiable 'tipping point' beyond which the law of diminishing returns applies for retrofitting projects (Gleeson *et al* 2011). While there are implications for procedural justice whenever a building is been renovated without the expressed consent of its occupiers, a survey of 251 social housing tenants whose homes had been retrofitted found that over one quarter of them (27.9%) were not given a choice as to whether energy efficiency measures were installed (Chahal *et al* 2012).

To build on Decent Homes, the Labour Government proposed introducing a more demanding 'Warm Homes' standard just before it left office (HM Government 2010a). This would have raised the required SAP rating for social housing up to 70, meaning that every home would have a minimum 'C' rating on an energy performance certificate. This policy has yet to be adopted explicitly by the coalition Government (Sunnika-Blank *et al* 2012). At the moment therefore, it is unclear exactly whether – and how – it will be delivered in England, although all social housing in Wales will still need to meet the higher standard by 2016/17 (Boardman 2012).

Energy Efficiency Commitment and Carbon Emissions Reduction Target

Through the Energy Efficiency Commitment (EEC), the Government set targets for fuel companies to reduce their customers' consumption by providing subsidies for residents to insulate their properties or install low-energy lighting. Although the main objective of the scheme was to reduce carbon emissions, it nonetheless had strong social objectives. For example, it aimed to deliver at least half of its energy efficiencies in 'Priority Group' households – those that were deemed at risk of fuel poverty or included vulnerable residents. By the time EEC came to a close in 2008, DEFRA (2006) estimated that about 80% of the £3.2 billion spent on both it and Warm Front would have been invested in Priority Group homes. As we have seen however, Warm Front was a particularly blunt instrument for tackling fuel poverty in the private rented and owner-occupied sectors, and since EEC was based on similar qualifying criteria, it is unclear whether these initiatives were directed at those most in need.

The Carbon Emissions Reduction Target (CERT) replaced EEC in 2008, and it requires all energy suppliers with a customer base in excess of 50,000 to reduce the amount of carbon dioxide emitted by households. Like the EEC, it is funded and operated by the utility companies and provides subsidies for all income groups to install low-energy solutions, although 40% of this money needs to be directed towards 'Priority Group' households. Energy companies have tried to deliver these reductions through a combination of consumer information, introducing 'green' electricity tariffs for customers and subsidising insulation measures. By March 2011, the scheme had supported 1.6m cavity-wall insulations, and over two million households had benefited from professionally-installed loft insulation. (DECC 2011c).

Both EEC and CERT (and indeed all other retrofitting schemes that are funded by the utilities) raise key concerns for distributive justice. This is because the costs of these schemes are recouped equally from all bill payers, regardless of their ability to afford the corresponding increase in energy prices (Mendonca *et al*, 2010; Hills 2012). Boardman (2012) has calculated that the average household is paying an additional

£90 in fuel bills to fund schemes such as CERT (and its successor ECO, which is covered below), and well as initiatives like the renewables obligation and EU emissions trading scheme. Newer policies, such as feed-in-tariffs and smart meters, are likely to add at least £20 to this surcharge (Hills 2012).

Feed-In Tariffs

Feed-In Tariffs (FITs) have been in place in the UK since April 2010 and have particular justice implications. They involve the Government setting a fixed price for renewable power that is generated by small-scale producers and fed into the National Grid. Energy companies are then required to buy this power, at this fixed rate per unit, over a long period of time (Mendonca *et al* 2010). In the UK, FITs apply to producers of less than 5MW, although the guaranteed rate per unit varies depending on how the energy is generated and when the system was installed.

In the first year of their operation, just over 30,000 installations were registered for the scheme, with a total capacity of 108.3 MW. Solar PV accounted for most of this capacity, with 77.7 MW, followed by wind with 18.9 MW (Ofgem 2011). However, there is not yet any empirical research available to show how the benefits of FITs have been shared across the population, and therefore what their distributive justice implications may be. Since many of the technologies that they fund require significant up-front investment, it may well be the case that wealthier households have been more able to take advantage of the initiative. As such, Hills (2012) argues that the policy is likely to have a small but negative overall impact on fuel poverty, because lower-income households are left behind but contribute to its cost. Mendonca *et al* (2010) have acknowledged that there is a 'differential cost', which amounts to a surcharge, that all consumers pay for the electricity that is subsidised by FITs compared to that which is produced by more conventional means. The total cost of the scheme in the UK in 2010-11 was £14m, but this will increase significantly as more installations take place that qualify for the payments (Ofgem 2011). In Germany, where FITs have been in operation for almost a decade, this 'differential cost' totalled £4.5bn in 2008. Although fluctuating energy prices make it very difficult to predict how it will develop in future, it is estimated to be £4.6bn in 2020, before falling to £0.6bn by 2030 (Mendonca *et al* 2011). Even if the distributive implications of this surcharge are not regressive, they will nonetheless mean that some energy customers are essentially subsidising the fuel bills of others. In addition, some properties, especially flats and other higher density types of home, are unsuitable for installing the solutions that qualify for FITs.

However, some social landlords, including local authorities, have installed a significant number of solar panels on their homes (Local Government Association 2011). Under the terms of the scheme, *residents*, rather than specifically *property owners*, benefit from the initiative through lower fuel bills and a guaranteed price for each unit of energy they generate. This means that people who live in social housing that has been retrofitted in this way will also gain from having the technologies installed – and therefore the beneficiaries will not necessarily be solely those who can afford the up-front costs. For example, Newcastle City Council is installing solar PV panels on 2,500 homes between 2011 and 2013, which will benefit its tenants (Newcastle City Council 2011). Various other authorities had similar plans – at least until the guaranteed price per unit of electricity generated through solar PV was revised downwards in late 2011. These included Leeds City Council's aim of installing at least 1,000 solar panels on council housing, similar plans for 3,000 panels on Wrexham Council's homes and proposals by Waltham Forest to equip 1,090 of its properties with solar PV (Local Government Association 2011).

Green Deal

After taking office in 2010, the Coalition Government outlined its approach to retrofitting housing in the 2011 Energy Act. Key features of this Act are the 'Green Deal' and Energy Company Obligation (ECO). The Green Deal aims to encourage homeowners to improve the energy efficiency of their homes by ensuring that they have no up-front costs for the investment. Instead, this capital spending (which could total £10,000-£16,000 (Boardman 2012)) will be recouped through a levy on electricity bills over a period of years. Under a 'Golden Rule', these extra charges must amount to less than the expected savings that the retrofitting project will deliver over the "lifetime" of the solution, which the Government has calculated as 25 years. These additional charges will stay with the property, meaning that subsequent bill-payers will take responsibility for them, alongside the benefits of a more energy-efficient home.

In many cases however, potential retrofitting initiatives will not meet the Golden Rule – in other words, the property will require expensive retrofitting work that will not pay for itself through lower energy bills over the expected lifetime of the improvement measures. The "Carbon Saving Obligation", which will require energy companies to reduce the amount of carbon dioxide emitted as a result of domestic energy consumption by 520,000 tonnes per year by 2015, will focus primarily on those homes that cannot be retrofitted easily or cheaply. Through this mechanism, energy suppliers will co-finance retrofits to ensure that they meet the Golden Rule, and then be able to count all of the carbon savings that result from the activity against their annual target. The Government expects this obligation to support the installation of solid wall insulation in 380,000 homes by March 2015, and 1.5 million homes by 2022 (DECC 2011a).

Alongside the Carbon Saving Obligation, energy suppliers will also have an 'Affordable Warmth' obligation, which will require them to fund energy efficiency initiatives in low-income homes in the private rented and owner-occupied sectors. This obligation aims to help at least 325,000 low income and vulnerable households in hard-to-heat homes by 2015 (DECC 2011a). However, the Government will not require energy companies to reach out to these households and communities in order to encourage them to take-up Green Deal finance or ECO funding (DECC 2011a). This 'opt-in' nature appears to mitigate a number of procedural justice issues. Unlike the Decent Homes scheme for example, most households that take up the Green Deal will have chosen to do so (although some tenants in private rented accommodation may have this decision taken by their landlord). However, this approach actually raises significant concerns for procedural justice, because eligible households may not become aware of the scheme or find it easy to access – and they will suffer as a result.

The ECO initiative also has a number of distributive implications. The Government expects the energy companies to spend around £1.3bn on delivering the objectives, with around 25% of this money aimed at meeting the Affordable Warmth target and the remaining 75% directed towards meeting the Carbon Saving obligation. Therefore, as with EEC and CERT, this investment will be funded by an increase in energy bills and have a disproportionate impact on low income households, for whom spending on fuel makes up a greater proportion of their total income. This has led Hills (2012) to warn that the distributional impact of the ECO will probably be regressive, potentially limiting its impact on fuel poverty. In order to combat fuel poverty more effectively, Hills argues that a much greater percentage of ECO spending – around one-half, rather than the current figure of one-quarter – would need to be focused on lower-income households. Furthermore, by excluding social housing tenants from the Affordable Warmth obligation, there is a risk that some of the most vulnerable households in the UK will remain in fuel poverty, despite the fact that they will be subsidising energy efficiency improvements elsewhere through a levy on their electricity bills (Local Government Association 2012).

Similarly, the Carbon Saving Obligation is expected to be used almost exclusively to fund solid wall insulation, which raises further issues. The Government's consultation on the Green Deal makes the point that initiatives such as CERT and Warm Front subsidised the insulation of homes with cavity walls, and therefore these people have already benefited from subsidised retrofits. In addition, most cavity-walled properties that have not yet been retrofitted will meet the Golden Rule for investment. However, the high cost of solid wall insulation (which averages around £8,000 according to HM Government 2010a) means that people living in these older properties will receive larger overall subsidies than those who occupy homes with cavity walls.

Another important factor is that the Government is restricting funding from both the carbon saving and affordable warmth obligations to households in the private rented and owner-occupied sectors, on the basis that social housing has benefited from initiatives such as Decent Homes over recent years (DECC 2011a; Local Government Association 2012). As such, not all lower-income families will benefit from the new policy framework – particularly if Labour’s proposed Warm Homes standard is not adopted by the coalition.

Incentivising renewable heat

The Renewable Heat Premium Payment (RHPP) was launched in August 2011. This provides taxpayer-funded vouchers to households to help them buy renewable heating technologies, such as solar thermal panels, heat pumps and biomass boilers. The first phase of this scheme ended in March 2012, but a second phase began in May 2012 (Energy Saving Trust 2012; DECC 2012d). Properties that are on the mains gas grid are only entitled to apply for support to install solar thermal technology, which suggests that the scheme is targeted at those most in need. This is because households that rely on oil, liquid gas, electric or solid fuel heating tend to have much higher energy costs. The only other restrictions are that homes must already be insulated to a high standard (where practicable). As such, the RHPP is supporting those people whose homes not only require them to use expensive heating fuel, but also retain a greater proportion of the heat that it helps to generate. However, other household circumstances are not considered as part of the grant-awarding process, and therefore the scheme does not necessarily target (or benefit) the rural fuel poor.

In particular, it is notable that the level of uptake has been very low compared to some of the schemes that seek to improve the thermal efficiency of domestic properties. For example, just over 7,000 vouchers with a value of £5.5m were issued in the first phase of the programme – and less than 5,400 of these vouchers were redeemed (Energy Saving Trust 2012b). In addition, £4m of funding was shared between 24 social landlords, but it appears that not all of the £15m budget for Phase One was exhausted (DECC 2011d). This suggests that there may be procedural issues associated with the delivery of the programme, although no independent research into the scheme was found as part of this review.

The RHPP was intended as a precursor to the Renewable Heat Incentive (RHI), as it can provide useful data on how much heat can be generated through these retrofits. The RHI works on the same basis as FITs, in that small-scale generators are paid a fixed amount for every kilowatt hour of heat that they produce from renewable heating systems (DECC 2012e). It was launched initially for non-domestic properties in November 2011, but is set to be extended to homes from summer 2013 (DECC 2012e). Due to its recent launch, we did not find any assessments of its justice implications in the literature. However, like FITs, these technologies tend to be very costly to install, and therefore it is unlikely that low-income households will invest in them, unless they receive significant subsidies to finance the up-front cost through the RHPP (Hills 2012).

Minimum thermal efficiency standards for private rented property

Households in private rented accommodation have been largely ignored by previous policy initiatives. Properties in this sector have an average SAP rating of 49, and they are more likely to be rated G or be classed as 'non-decent' than owner-occupied or socially-rented housing (Boardman 2012). The Government has recognised that progress in improving the thermal efficiency of these properties has lagged behind that of other sectors (HM Government 2010a). As a result, the 2011 Energy Act will also mean that from 2018 it will be illegal to rent out properties (either as homes or for non-domestic use) that have an energy performance certificate rating of either F or G (Boardman 2012). This is expected to affect 680,000 homes and benefit up to 14% of those in fuel poverty. As Boardman (2012) points out, over a third of privately rented homes are vacated annually and the average length of a business lease has fallen to five years. Therefore, the impact of this new requirement on private rented property could be rapid – and benefit people who may have been excluded from previous retrofitting schemes. However, if the improvements that are necessary to upgrade homes are funded through Green Deal finance, current and future tenants will essentially be paying for home improvements through higher fuel bills. As such, it could be argued that they will be subsidising work that should otherwise be funded by their landlords, and also that future tenants will have had no input into the decision to retrofit their homes.

Non-residential buildings

There are around two million non-domestic buildings in the UK, which account for 17 per cent of the country's carbon emissions (DCLG 2009; Boardman 2012). The rate of growth in energy consumption in non-domestic property has been three times greater than in housing since the 1970s (Scrase 2001). However, there are several barriers to retrofitting in this sector, including the heterogeneous nature of non-domestic property (Bruhns et al 2000), the complexity of the market and the fact that most commercial property is not owner-occupied (Rhoads 2010). Together with the absence of an identifiable group of people who may be in a non-domestic equivalent of fuel poverty, it is perhaps not surprising that a comprehensive policy has not developed for this sector. Instead, the Government has tended to rely on competitions (DECC 2012c) and market mechanisms to try and stimulate retrofitting in non-domestic property.

These market-based mechanisms include the Carbon Reduction Commitment, which requires organisations whose electricity consumption exceeds 6000 MW hours per year to pay a surcharge on the energy they consume that does not come from renewable sources. Other initiatives include the requirement for all rented property to reach a minimum energy performance certificate rating of E from 2018, which was discussed on page 22. There is emerging evidence that 'greener' commercial buildings are becoming more attractive to businesses (Royal Institute of Chartered

Surveyors 2012), which suggests that this market-based policy is having an impact (see also UK Green Building Council 2008; Boardman 2012; Gleeson *et al* 2012).

Alongside these market mechanisms, some of the more recent schemes that have been targeted primarily at the housing sector (such as the Green Deal or FITs) are also open to non-domestic properties. Conversely, the Renewable Heat Incentive (RHI, see page 21) was aimed initially at businesses, and is set to apply to households from summer 2013. This initiative provides taxpayer-funded subsidies for the installation and running of renewable heat, with a budget of £860m until 2014/15, and will be extended to domestic properties from summer 2013.

There is some evidence that public, private and voluntary organisations are beginning to take advantage of these schemes. For example, Birmingham City Council, the largest local authority in the country, hopes to use the Green Deal to finance a £1.2bn retrofit of public buildings in the West Midlands (Clark 2011). The Salix funding scheme (which is run as a social enterprise but funded by the Government) provided various public bodies with capital funding to install energy efficient technologies. These have included a combined heat and power plant for Bradford University, numerous boiler replacements and other smaller-scale projects in local government, education and the NHS (Salix 2012).

In 2009 and 2010, English councils were also judged on their use of natural resources as part of the Audit Commission's Comprehensive Area Assessment. This took account of the authority's consumption of energy, water, minerals and other non-renewable resources (Audit Commission 2009). As such, it required councils to measure and report this information to auditors in 2009 and 2010 (the assessments were abolished after the coalition government took office). In recent years some authorities have installed energy-saving solutions such as low-energy street lighting or swimming pool covers, or sought to change the fuel requirements of their vehicle fleets (Improvement East 2009). However, it is unclear how much these retrofits were driven by the inspection regime, rather than the result of financial considerations such as the cost of fuel.

Progress in the private sector has been less rapid. As Femeni and Fudge (2010) argue, energy costs only represent a fraction of some businesses' total costs, and therefore managers often have more pressing concerns. Indeed, their analysis of non-domestic retrofits in Bristol found that they were driven primarily by commercial objectives and local community regeneration, rather than environmental considerations (Femeni and Fudge 2010).

Spatial Impacts of Retrofit Programmes

There is limited analysis of the spatial impacts of retrofitting programmes. Hills (2012) found no significant difference between levels of fuel poverty across English regions, and only a weak concentration of fuel poverty in areas of general deprivation. Yet it is not clear whether the situation was any different before the Government began its concerted attempt to tackle fuel poverty, or whether it has changed as a result of the various policies that have been implemented. In its impact assessment for the Green Deal, the Department for Energy and Climate Change argued that each part of the UK received "its fair share" of support from previous government initiatives (DECC 2011b). However, a household survey suggested that suppliers experienced some barriers when installing retrofits in metropolitan and remote rural areas, as well as blocks of flats (DECC 2011b).

An analysis of those areas of England that were entitled to funding through the Community Energy Saving Programme (CESP, see below) shows that these were disproportionately concentrated in northern regions and in urban areas (DECC 2009). However, the distribution of CESP is not surprising, since this initiative was targeted at areas of low-income and therefore reflects existing regional disparities. In addition, other factors are also in play regarding eligibility for CERT, such as the prevalence of properties with cavity walls or lofts that can be insulated easily (DECC 2011b). These exclude many homes in London, for example, due to the high percentage of households living in flats.

Hills (2012) found that the average fuel poor household in the countryside would need to have an additional £622 to spend on fuel every year to heat their home to an adequate standard. In contrast, the average fuel poverty 'gap' in towns and cities is just £362. The vast majority of neighbourhoods that have benefited from CESP are in urban areas, and it may be the case that the countryside has been overlooked in many of these initiatives. One key factor in this is the fact that most rural properties are not connected to the mains gas grid. As such, they are reliant on more expensive fuel for heating, such as oil or electric storage heaters. The RHPP has sought to address this issue, but it is only a small-scale, temporary scheme, and take-up has been low (DECC 2012d). Moreover, homes in the countryside are more likely to have solid walls and be less thermally-efficient, largely due to the fact that over half of them were built before 1919. Indeed, the Commission on Rural Communities (2010) found that 60% of homes in urban areas and rural towns are cavity walled and on mains gas, compared to only 32% in villages and 21% in hamlets. In other words, they are harder to insulate than urban properties and have relatively high fuel costs as a result. Nonetheless, awareness of the various schemes that are available to support retrofitting projects may be lower in rural areas, not least because they do not qualify for locality-wide programmes such as the CESP. As a result, it is possible that people in the countryside are not receiving a fair share of the benefits of retrofitting policies.

This landscape of initiatives and subsidies has led some to criticise the UK government for relying on "piecemeal interventions", rather than a comprehensive strategy for market transformation (Boardman 2012; Killip 2012). Indeed, in spite of aiming to target fuel poverty, the net result of these policies has been regressive – the fuel poor have received less in benefits than they have contributed (Hills 2012). Boardman (2012) argues that this situation will actually worsen if a large part of the ECO is used to subsidise better-off households by helping to fund solid wall insulation.

Community Energy Saving Programme

The Community Energy Saving Programme (CESP) was launched in 2009 and aims to deliver economies of scale by providing 'whole house' retrofits to homes in 4,500 deprived areas across Britain. Specifically, it targets the poorest 10% areas in England, and the poorest 15% in Scotland and Wales. As with a number of the schemes that are aimed at individual buildings, it is funded by the energy companies through a levy on bills, and driven by an obligation on suppliers to help customers reduce their consumption. All households within the area are eligible for the support, not just those that are claiming particular benefits, include vulnerable occupants or occupy thermally inefficient homes. Therefore, it is probable that people who are experiencing fuel poverty are able to access the programme by virtue of living in an area where incomes are significantly below average. Additionally, other households in these areas who are not in fuel poverty may also receive the support, regardless of whether they need it or not. However, there appears to have been no independent research into this.

Integrated locality-based retrofits

Apart from CESP, which can be viewed as an extension of the various initiatives that have aimed to combat fuel poverty through improving the thermal efficiency of housing, central government has not set out a coherent framework or strategy for retrofitting localities. This is in spite of the fact that several policy-making actors have called for an integrated approach to urban renewal, community engagement and sustainability (Sustainable Development Commission 2010; Sustainable Housing Action Partnership 2011). These have stressed the benefits and justice implications of retrofitting whole areas, not just the buildings that are situated within the locality. Indeed, the Sustainable Development Commission (2010) argued that area-based approaches can be far more effective than focusing on individual buildings, but found that the lack of a single co-ordinating body often meant that these retrofit programmes did not deliver their potential sustainability benefits. Whilst there has been some pressure for the Government to encourage the financing of community retrofits through the Green Deal (Coyne 2012), this has not resulted in any concrete policy instruments.

The Commission highlighted the approach taken by Greater Manchester to develop a strategic programme of area-based retrofitting that also supports job creation and integrates other initiatives to improve quality of existing places. In 2009 Greater Manchester was designated as the UK's first Low Carbon Economic Area and the city-region set out a five-year plan for retrofitting through a range of co-ordinated neighbourhood activities. The plan includes a focus on developing new retrofitting technologies and benefits for local businesses, supply chains and employment levels (Sustainable Development Commission 2010; AGMA 2009). It aimed to double the number of people employed in the environment technology, goods and services sector by 2015. It stresses the benefits of an area-based approach as including:

- Increasing the opportunities for funding retrofits
- Procuring technology collaboratively to reduce unit costs and help organisations purchase 'state of the art' facilities that would otherwise not be possible.
- Ensuring that the supply of retrofitting solutions meets demand.

In addition to reducing carbon emissions by an additional 1.8m tonnes and delivering other 'quality of life' benefits to residents, the programme expects to generate an additional £500m in Gross Value Added for the conurbation. Indeed, the Delivery Plan states that "the LCEA is firstly and most importantly an economic development programme, which will also help to deliver carbon reduction targets" (AGMA 2010, 9). In this vein, its retrofitting focus appears to be exclusively on reducing carbon emissions from buildings and does not cover other sustainability considerations in any depth.

District heating

The approach towards district heating, which is the principle source of domestic heating in various European countries (Gleeson *et al* 2011) and one that has significant potential to reduce carbon emissions, demonstrates how central government has taken a 'hands-off' approach to retrofitting localities. In 2010, the outgoing Labour Government published an 'enabling framework' for district heating and cooling (HM Government 2010b). The coalition followed this two years later with a paper on low-carbon heat, which includes a section on the potential role of district heating networks (DECC 2012b). Both papers detail how these networks have been installed in cities such as Sheffield, Nottingham, Southampton, Birmingham and Aberdeen, and acknowledge their potential sustainability benefits. In this context, the Government is committed to "work with local authorities to ensure they are aware of the tools available to them, including through the planning system, to create the conditions best able to support development of heat networks" (HM Government 2010b, 6).

Retrofitting infrastructure for climate adaptation

In the context of climate change, it is expected that a comprehensive area-based retrofit would cover open spaces and infrastructure, as well as buildings, and therefore include projects to increase the amount of green space in cities to provide cooling, improve air quality, and create habitats for biodiversity (Wigmore 2009). Such ideas have been adopted with gusto by the Mayor of London, who promised to plant 10,000 'street trees' in the capital by 2012 and increase tree cover in the capital from 20 per cent to 25 per cent by 2025 (Mayor of London 2012).

As Lindley et al (2011) argue 'climate disadvantage' is determined by a combination of the likelihood and degree that an individual or group may be exposed to an environmental hazard, as well as their 'social vulnerability' to such hazards. It takes account of the extent to which people can adapt their property to extreme climate impacts, considering factors such as their ability to relocate or take out insurance against flood risk. Given that poorer households are more likely to be vulnerable to flooding than people with higher incomes (Thrush *et al* 2005), a hands-off approach to retrofitting urban areas for adaptation objectives has implications for distributive justice. Power (2008) has argued that many modern homes will not be able to withstand severe weather events such as high winds, very heavy rainfall or frequent flash flooding, and therefore policymakers should seek to adapt the homes of the most vulnerable to ensure that they are not severely affected. Ashley *et al* (2011) are critical of the lack of guidance to help local authorities upgrade local drainage systems. The London Borough of Sutton, working with Manchester University, has developed a toolkit that allows users to view climate change risks and vulnerabilities in their areas, with a view to these feeding into improved planning policies and decision-making (London Borough of Sutton 2010).

Retrofitting jobs

Alongside the social and environmental benefits of retrofitting, another key argument for Government action in this areas has been to stimulate the 'supply side' of the equation and help develop retrofitting businesses as part of a wider shift towards a low-carbon economy. Some have disputed the extent to which 'green jobs' can be created (Global Warming Policy Foundation 2011). However, a range of politicians, academics, industry and trade unions have argued that they could be some kind of 'silver bullet' that simultaneously solves a number of contemporary ills: reversing deindustrialisation, diversifying local economies, making up for the loss of employment in traditional, polluting industries and representing the opportunity for cleaner, less hazardous jobs and a more skilled workforce. In 2009, a consultancy commissioned by the UK government estimated that a total of 400,000 potential jobs could be created by 2015 if plans to reduce emissions were realised (Innovas 2009). More specific analyses of the retrofitting industry predict that the market for green refurbishment could be worth between £3.5 billion and £6.5 billion per year to the UK (UK Green Building Council 2008; Radian 2010). The Government hopes that up to 65,000 people will be employed in jobs such as installing retrofitting solutions and providing energy efficient advice (HM Government 2010a). These figures are not necessarily unrealistic; according to Bird and Lawton (2009), almost 1.5 million jobs were created in the US between 1972 and 2007 as a result of household energy efficiency measures.

In spite of this optimism, the Government has taken a *laissez-faire* approach to the development of a low-carbon economy, perhaps expecting that the market would respond to the demand it creates from encouraging domestic insulation programmes. For example, it recognises that the number of external and internal wall insulation installers needs to increase over the next ten years to undertake the retrofitting that will be triggered by the Green Deal (DECC 2011). The 2011 Budget announced that 1,000 Green Deal apprenticeships would be created to try and meet this demand (HM Treasury 2011), but these are unlikely to be sufficient, given that there are over seven million properties with solid walls in the UK (Coyne 2012). In short, apart from some subsidies and tax breaks, there have been few initiatives to stimulate the supply side, such as state-funded training programmes to help people develop the necessary skills to undertake some of the required work.

Indeed, several organisations and academics (Bird and Lawton 2009; 2010; Royal Academy of Engineering 2010; Morris 2012) have lamented the lack of state support for such initiatives, particularly in contrast to countries such as Germany and Denmark (TUC 2009). Others have highlighted a lack of awareness of retrofitting techniques amongst building professionals (UK Green Building Council 2008; King 2010; Gallo and Nelli 2012). Bird *et al* (2010) argued that the UK's approach to 'joining-up' the retrofitting agenda with the 'green jobs' agenda trails that of the US, in spite of the traditional American preference for market-based solutions. In part this may be because employers are not able to articulate what might be needed, particularly for 'deep retrofits' – major renovations of the type that will be necessary to deliver the required level of carbon reductions (Gleeson *et al* 2011). In other words, there is insufficient actual demand for skills at the moment, although this may change as employers' requirements become clearer (ProEnviro 2010).

Nonetheless, the scale of retrofitting activity that has been undertaken over the last fifteen years does suggest that a large number of jobs have been created to meet this demand. Indeed, some local authorities in the north of England tried to use the Decent Homes initiative to stimulate employment and training opportunities for local people (Bennington *et al* 2011). However, there has been no comprehensive analysis of how retrofitting work has been shared across the labour market, and therefore what the distributive justice implications may be. For example, Eaga (now Carillion) was the main contractor for the Warm Front scheme, and its headquarters were in the North East of England. A greater proportion of homes have been retrofitted through Warm Front in the North East and North West regions of England than any other (Sefton 2004). Yet it is unclear whether Carillion employed people from older, less efficient or polluting industries in these areas, or if it has displaced them, and attracted a new, specially trained workforce from elsewhere in the country or from a younger demographic.

Very few published studies were identified that addressed these issues, although Baldwinson (2012) has undertaken an assessment of the North West Construction Knowledge Hub, a project that provides support to small and medium size construction companies in the North West of England. He found that the project had provided more retrofitting assistance to firms based in lower-income areas, something that he attributes in part to a focused marketing and engagement strategy which built on pre-existing relationships in deprived neighbourhoods. Nonetheless, this small case study does suggest that some of the retrofitting work is being distributed to those areas that may suffer under-employment.

One key issue is whether retrofitting work can be delivered by the existing construction sector with little additional training. Currently, refurbishment is estimated at around 40% of the UK construction sector in value terms (Baldwinson 2012). On this basis, it is perhaps reasonable to assume that existing companies will be well placed to win retrofitting contracts, particularly if they do not require hi-tech solutions. Therefore any analyses of how the benefits of retrofitting work are distributed should perhaps take account of existing construction employment.

Related to this is the extent to which retrofitting industries provide 'good' jobs; that is, whether they are well-paid, highly-skilled, full-time, permanent positions that are open to a range of people in those areas where there is surplus labour. Since the financial crisis of 2008, unemployment has risen most sharply in those parts of the UK that already experienced relatively high levels of joblessness, and which relied more heavily on manufacturing and construction (Bird *et al* 2010). As many retrofitting companies require people with these skills, employing them might be seen as an ideal solution. However, as Bird and Lawton (2009) argue, manufacturing and construction have traditionally offered limited opportunities to women. Therefore, the potential for these jobs to disproportionately benefit one sex over the other should also be considered in any assessment of distributive justice.

Although central government has largely adopted a hands-off approach to supporting low-carbon industries, some local authorities have been more pro-active and sought to integrate the supply of and demand for retrofitting solutions. For example, Bird and Lawton (2009) described how Birmingham City Council has formed a partnership with various local organisations to improve energy efficiency in buildings across the city and also provide employment opportunities for local people. The partnership tries to ensure that contractors recruit from deprived areas of the city (although this has been hampered by EU procurement rules that require authorities to advertise public contracts to all potential bidders) and hopes to create around 270 jobs and apprenticeships by 2026. Another local authority, Kirklees Council in West Yorkshire, set up a partnership to deliver home energy assessments and insulation to thousands of homes in the borough. According to the Sustainable Development Commission (2010), this policy led to the creation of over 100 jobs per year over a three-year period, an additional 29 jobs in supply chains, and the establishment of a depot and training centre nearby. It is unclear whether the beneficiaries of this policy are local, vulnerable or unemployed, but the example suggests that Kirklees' decision to act early on this issue meant that it was a 'first mover' in the market for solutions. As a result, it ensured that its citizens would benefit in terms of both receiving and delivering retrofitting solutions.

European comparisons

Direct comparisons of retrofitting activity in other countries can be difficult, due to the number of variables in play. For example, the prevalence of houses rather than flats makes comparisons with many continental countries problematic, countries with warmer climates have different retrofitting priorities, the various ages of property affects how urgent retrofitting may be, and the percentage of homes that are owner-occupied varies considerably. Gleeson *et al* (2011) provide a detailed discussion of the difficulties associated with developing a common methodology for comparing the retrofitting approaches of different European countries, and Meijer *et al* (2009) highlight some of the significant differences in building and tenure types across eight European countries.

Nonetheless, McEvoy *et al* (2012) compared the retrofitting of 100 housing association properties on the Isle of Sheppey with a similar project in Boulogne. They found that the two countries have very different approaches towards engaging residents with the upgrade. The English housing association was trying to re-brand the whole neighbourhood, and viewed the retrofitting project as part of a programme to transform the appearance of the homes. However, the interspersion of owner-occupied housing on the estate (purchased by tenants through the right to buy scheme) meant that this was not possible. In contrast, its French counterpart adopted a more technocratic approach and was able to raise the standard of environmental performance much more, as well as benefit from economies of scale through shared amenities such as district heating. As such, McEvoy *et al* (2012) showed how an approach that may be fairer in procedural terms (because it involves residents much more in the process of retrofitting), may not actually deliver all of the benefits that are possible.

Germany is often held up as a world leader in domestic retrofitting (Galvin 2010), having been one of the first countries to introduce FITs on a wide scale (Mendonca 2010) and setting the 'gold standard' for thermal efficiency in both refurbished and new buildings (the *Passivhaus*). Since the early 2000s, the German federal government has provided subsidised low-interest loans (fixed at 2.65%) to landlords and homeowners that want to retrofit their property (Boardman 2012). Some city authorities, including Munich and Freiburg, provide additional grants and subsidies, and around 170,000 German households have taken advantage of the scheme annually, suggesting that there is some demand for it (Boardman 2012).

However, this finance is only available if the renovation project will bring the building up to the same exacting standards that are required for new buildings. Galvin (2010) criticises this approach as being cost-ineffective, as it means that the only retrofits that can be funded through this mechanism are very expensive, and therefore property owners need to borrow a significant amount of money to fund them. In spite of this concern, Spain adopted a similar policy from 2008 (Gleeson *et al* 2011). No detailed analyses of either country were found in this literature review, but it seems likely that lower-income households would be less able to take out a loan of this magnitude and landlords may be reluctant to borrow such a large amount to fund a benefit for their tenants.

Conclusions

The broad definition of "retrofitting" that has been adopted for this review highlights the range and complexity of associated issues for distributive and procedural justice. In particular, analyses such as Boardman (2012), the National Audit Office (2009) and particularly Hills (2012) suggest that government policies aimed at improving the thermal efficiency of domestic property have not necessarily benefited those who are most in need. Although the Decent Homes programme has resulted in significant retrofitting in social housing, and Warm Zone and CERT have delivered improvements to millions of homes across the country, the blunt nature of these instruments has meant that a large percentage of the population did not benefit from them and remain in fuel poverty. Moreover, the new Green Deal landscape, which incorporates ECO and the Affordable Warmth obligation, is likely to be even more regressive, because these funding mechanisms will be financed through a levy on electricity bills, rather than general taxation. In short, the initiatives that have aimed to tackle fuel poverty have generally been unsuccessful, partly due to problems associated with identifying the 'fuel poor'.

In contrast to the numerous initiatives on home insulation and energy generation, central government has produced remarkably little to support the retrofitting of localities for climate adaptation or other sustainability objectives. Existing risks, hazards and disadvantages faced by vulnerable groups could be exacerbated if residential and urban areas are not adapted to deal with severe weather events, for instance. Similarly, the Government's relatively *laissez-faire* attitude towards developing a retrofitting industry could mean that the benefits of employment and economic growth are not distributed fairly. In this way, the very absence of policy has its own implications for justice.

Finally, the literature highlights the lack of a coherent retrofitting strategy that integrates issues of justice with the energy efficiency of domestic and business property, urban renewal, climate adaptation and green jobs. Instead, the Government's 'scattergun' approach to many of these interconnected issues has meant that the country as a whole has not benefited sufficiently from retrofitting opportunities, and certain groups of people may actually be more vulnerable than before.

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ANNEX: Relevant Recent and Current Retrofit Research Projects

Retrofit 2050 Project

Salford University, in partnership with Cardiff and Oxford Brookes Universities and the University of Cambridge are carrying out the EPSRC-funded Retrofit 2050 project. See the recently launched website at www.retrofit2050.org.uk . This research specifically sets out to ask:

How do cities develop the knowledge and capability to systemically reengineer their built environment and urban infrastructure in response to climate change and resource constraints?

It is looking at "what" is to be done to the city (technical knowledge, targets, technological options, costs, etc.) and "how" will it be implemented (institutions, publics, governance). The project grew out of the ESRC/Arup funded placement programme undertaken by Salford with ARUP. It aims to explore urban scale retrofitting as a managed socio-technical transition, focusing on prospective developments in the built environment - linking buildings, utilities, land use and transport planning – to develop a generic urban transitions framework for wider application. The geographical focus is on the Cardiff region and Greater Manchester. Commercial collaborators include Corus and Arup. Regional collaborators include Cardiff and Neath Port Talbot Borough Councils, WAG and AGMA/Manchester City Region Environment Commission.

Objectives include:

- Explore and advance both theoretical and practical understandings of processes of systems innovation and transition in an urban context;
- Analyse through case studies, modelling and international comparison, the technical and social processes underpinning such transitions;
- Identify and characterise prospective disruptive technologies and systems innovations which will underpin a transition to sustainability in the built environment (over the period 2020-2030);
- Articulate and appraise regionally specific visions and prospective pathways for urban scale retrofitting of the built environment.

The project aims to mobilise expectations around clearly articulated roadmaps, pathways & scenarios for prospective disruptive technologies and systems innovations; develop an integrated urban scale modelling and evaluation tool to support improved decision-making and implementation; and develop a national & internationally leading centre on the future of urban retrofitting.

4M: Measurement, Modelling, Mapping and Management 2008 – 2012

Led by Loughborough University, in partnership with the Universities of Newcastle, Sheffield, Leeds and De Montfort, its aim is to develop tools for the benchmarking and management of carbon sources and sinks in UK cities. Based on the City of Leicester as its case study, it is mapping the carbon produced by buildings and traffic, together with the carbon sinks associated with green spaces, using new and existing data and the development of models. In particular it is assessing the likely impact of a range of interventions, including district CHP, domestic micro-generators, energy efficiency measures and changes in transport technologies and management.

SECURE: SElf Conserving URban Environments 2011 - 2015

The SECURE project, led by the University of Newcastle, with Loughborough, Exeter and Sheffield Universities, is developing a range of future regional urbanization scenarios, and exploring their consequences for resource demand and provision (including transport, dwellings, energy, water and waste). It aims to create an integrated suite of models, at *macro*-(regional) scale, of urbanisation, ecosystem services and energy supply and demand, which can be used to predict household resource demand and infrastructure requirements, and investigate scenarios to enhance efficiency and conservation. Project partners include the Department for Transport, local government, utilities and private sector companies. North East England will be a test bed for the development and evaluation of transitional scenarios leading up to 2050 aimed at quantifying the benefits of integration of resource conservation across the themes.

SUME: Sustainable Urban Metabolism for Europe 2008-2011

An FP7 research project led by the Austrian Institute for Spatial Development to analyse the impact of urban forms on resource use and estimate the potential to transform spatial structures to significantly reduce resource and energy consumption. The project compared Newcastle-upon-Tyne, Vienna, Oporto and Stockholm. Among its findings, are the recommendations that:

- All urban growth and the life-cycle turnover of built structures should be used as potential to improve the existing urban form, both in terms of spatial structures and object qualities.
- Larger urban development projects can be located and serviced with infrastructure in such a way that they improve the overall performance of a city/agglomeration, not just that of the specific project.
- Ongoing relocation and renovation activities have the potential to improve urban form qualities over time, if consistently guided spatially with the resource-efficiency objective in mind.
- Renovation and building rehabilitation programmes for urban quarters should reach beyond solely improving thermal qualities, but include raising inner-city attractiveness and putting metabolism-relevant technology in place.

See www.sume.at

SNACC: Suburban Neighborhood Adaptation for a Changing Climate

SNACC is funded by the EPSRC, under the Living with Environmental Change Programme (LWEC) and is part of the Adaptation and Resilience to a Changing Climate (ARCC) Coordination Network. It focuses on adaptation to climate change but mitigation aspects are included. Partners are University of the West of England, Oxford Brookes University, Heriot-Watt University, Stockport Council, Oxford City Council, Bristol City Council, White Design and ARUP

It seeks to answer the question:

How can existing suburban neighbourhoods be best adapted to reduce further impacts of climate change and withstand ongoing changes?

The research focuses on adaptations to the built environment, through changes to individual homes and larger neighbourhood scale adaptations (urban re-design). SNACC focuses on suburbs as the most common type of urban area in the UK, housing 84% of the population. It aims to identify successful adaptation and mitigation measures: these are classed as those that perform well technically (i.e. they protect people and property from climate change impacts and mitigate against further climate change) but are also those that are the most practical and acceptable for those who have to make them happen.

The project uses 6 neighbourhoods from 3 cities as case studies (Bristol, Oxford and Stockport). In these areas, key agents of change (e.g. home owners, elected members and planners) will help to determine successful adaptations. The project team will use modelling (of climate change, house prices and adaptation outcomes), tools that allow the participants to visualize what 'adapted' neighborhoods will look like, and deliberative methods from social sciences, to generate a portfolio of adaptation strategies that are feasible, and fully endorsed by stakeholders.

See Williams, K. Joynt, JLR and Hopkins, D. (2010). 'Climate change and the compact city: the challenge of adapting suburbs', Built Environment, 36 (1), 105-115.

The Land of the MUSCos: Multiple-Utility Service Companies 2011-2014

A project led by Leeds University, with Cranfield University and the Universities of Edinburgh, Newcastle, Exeter and Oxford Brookes Universities. This research examines and promotes the establishment of Multi-Utility Service Companies, or MUSCos. The defining characteristics of a MUSCo are that it is the single point of service to multiple utilities; and profits from service delivery, not selling physical products. The emphasis on service delivery represents a paradigm shift away from the supply and demand of physical flows (energy, water, etc.) to the supply of services (ambient temperature, illumination, food preservation, cleanliness, etc.). The lower the energy and water consumption of its clients, the higher the MUSCo's profit - as long as the MUSCo maintains the requested level of service provision. The ultimate goal is the radical expansion of the best possible technology and efficiency measures, leading to large verified savings in resource use and reductions in carbon emissions.
The methodology is based on the combination of three complementary components:

- The investigation of multi-utility service contracts (including technical challenge of defining integrated services with possible substitutability of utility streams to satisfy the service demand).
- The survey of the governance landscape, regulatory and incentive structures of the different utilities, producers, distributors and other connected actors, to map the drivers, motivations and constraints of the current entities; and
- The combination of these two streams of information into an integrated socio-technical model using the rules and inter-linkages defined in the previous components and capable of exploring future governance and technical scenarios.

Heat and the City: Sustainable Heat and Energy Efficiency in Municipal Communities (2010-2014)

This project by the Universities of Edinburgh and Strathclyde looks at the development of sustainable and low carbon heat systems in Northern European cities. Funded under the RCUK Energy and Communities Initiative, it aims to "create a blueprint for catalysing transitions to sustainable heat in 'cold climate' cities", using case studies in Glasgow and Edinburgh. The project has a strong emphasis on collaboration with public, private and community promoters of new projects.

CLUES: Challenging Lock-in through Urban Energy Systems 2010-2012

The CLUES project, led by UCL, aims to critically assess the development of decentralised energy systems in urban areas in the light of national decarbonisation and urban sustainability goals. It examines the range and types of urban energy systems that are and might be installed. It further considers the issues raised by the need for such initiatives to integrate with energy systems at urban level in the UK, regional and national scales in order to deliver energy and carbon reductions to 2050 effectively.

Optimizing Value Propositions for Energy Efficient Renovations
The aim of this project at the Universities of East Anglia and Sussex is to assess the acceptability to UK homeowners of alternative value propositions for energy efficient home renovations in the Green Deal-enabled market, and to identify the optimal value propositions for accelerating the diffusion of efficiency measures through the UK housing stock. The main objectives will be to systematically test the attractiveness to UK homeowners of different value propositions for energy efficient renovations, to improve the rigour of empirical data and research findings about the UK retrofit market and to develop a freely-downloadable market simulator. The project team includes B&Q, the UK's largest home improvement retailer, and the Low Carbon Innovation Centre, based at the University of East Anglia.

Industrial Energy Use from a Bottom-up Perspective
This project by the Universities of Bath and Oxford, the UCL Energy Institute and the Environment Agency aims to evaluate industrial energy use and improvement potential (and associated CO2 savings) via bottom-up case studies set within a context of UK industry-wide understanding. Earlier top-down, UKERC-sponsored research at the University of Bath is being used to identify the technical retrofit combinations that might yield the greatest improvement potential going forward. Data obtained will be collated with the purpose of providing for the modelling needs of UK policy makers (e.g., the Committee on Climate Change (CCC), at DECC and the Environment Agency). Specific objectives are:

- To provide a bottom-up assessment of the energy improvement potential and greenhouse gas (GHG) reductions in a range of important UK industrial sub-sectors, based on engineering approaches, and differentiating between 'traded' and non-traded sector emissions;
- To set this data in the context of an industry-wide, top-down evaluation of the overall improvement potential of UK industry;
- To disaggregate the energy and CO2 implications of the studied sub-sectors;
- To provide information in support of the industrial modelling needs of UK policy makers, including the potential impact of fuel switching and the identification of difficult sectors/processes and areas where investment could be targeted most effectively.

Scenarios for the Development of Smart Grids in the UK
The project at the University of Westminster examines the factors that might influence the potential for Smart Grids, how such grids can develop from today to 2050 and who might be the winners and losers in this process. Scenarios are seen as a key tool for decision-making. While existing scenarios highlight social, economic, policy and technological drivers of change within energy and related sectors, this work aims to examine the roles and priorities of different actors, spatial variation or behavioural issues. The work will build the interaction of different actors into the scenario development process to incorporate pace and scalability of technology deployment, cost and finance, organisational and business models involved, regulatory style, the role of users, and international drivers and linkages.

Retrofit for the Future

In 2009, the Technology Strategy Board (TSB) implemented a £17m programme known as Retrofit for the Future (RfF), to kick-start the retrofitting of the UK's social housing stock. AECB – the sustainable building association was asked to develop appropriate energy performance targets for the competition and provide ongoing support and guidance. Phase 1 saw 194 design and feasibility studies developed, while Phase 2 took 86 of these studies and funded the implementation of the retrofits proposals. All 86 RfF projects that were accepted for Phase 2 funding are included in a web-based database at http://retrofitforthefuture.org.uk as an education and dissemination tool, incorporating both the RfF projects and other new and refurbished *domestic and non-domestic* low energy buildings.

EVALOC: Evaluating the impact, effectiveness and success of DECC-funded low carbon communities on localized energy behaviours 2011 - 2013

A 3-year £1.14 million RCUK/ESRC funded research project, under the Energy and Communities Programme, which brings together an interdisciplinary team of researchers from building science and social science disciplines based in the Low Carbon Building Group of Oxford Brookes University and the Environmental Change Institute of University of Oxford.

EVALOC is working with six low carbon community groups to evaluate their impact on changing individual and community energy behaviours, their effectiveness in achieving cuts in energy use and carbon emissions, and their success in bringing about sustained and systemic change. In addition to the academic focused outputs, the research will produce materials and guidance for community energy projects, covering engagement, methods and evaluation plus community energy monitoring data, materials and map based tools.

Smart Communities

Led by Kingston University, this 3-year project brings together a community to discuss, develop and adopt new energy-saving behaviours and decisions. It explores the social norm approach, with a focus on the interaction between individual members and the progress of the community as a whole.

RESOLVE

This is a cross-disciplinary research programme in the University of Surrey led by Tim Jackson. Its main areas include:

- Development and testing of robust, pragmatic energy and carbon mapping framework based on input-output, LCA and structural time series modelling.
- Exploration of underlying (direct and indirect) energy demand trends by functional headings and lifestyle 'clusters'.
- Extension to social and socio-structural variables using Social Accounting Matrices. Social and environmental psychological influences on energy behaviours and understandings of resistance to change.
- Elaboration and testing of a 'threatened identity' model of resistance to change.
- The role of social norms and the communal management of social and environmental resources.
- Elaboration and testing of lifestyle scenarios, using energy mapping and informed by socio-psychological and cultural understandings of lifestyle change: a longitudinal empirical case study.

Resilient Futures 2010-2014

This project is led by the University of Southampton It will consider future developments in the UK's energy and transport infrastructure and the resilience of these systems to natural and malicious threats and hazards, delivering a) fresh perspectives on how the inter-relations amongst our critical infrastructure sectors impact on current and future UK resilience, b) a state-of-the-art integrated social science/engineering methodology that can be generalised to address different sectors and scenarios, and c) an interactive demonstrator simulation that operationalises the concept of resilience for a wide range of decision makers and stakeholders. Partners include Newcastle City Council and Tyne and Wear Emergency Services.

The iConnect Project 2008-2013

iConnect is funded by the EPSRC to integrate the perspectives of public health and transport research in the measurement and evaluation of the travel, physical activity and carbon impacts of the Sustrans programme improving pedestrian and cycle routes in the UK (Connect2). It involves a consortium of universities, including Bristol, Oxford and Strathclyde. The first research objective of the iConnect project is to develop an applied ecological framework by which current theories about the behavioural effects of environmental change may be tested in heterogeneous and complex intervention settings. The iConnect evaluation framework draws on classic epidemiological methods, psychological and ecological models of behaviour change, and the principles of realistic evaluation. The framework, and associated tools to measure travel behaviour, physical activity, carbon emissions and energy use (and their inter-relationships), are then applied at three 'core' Connect2 case study sites (Cardiff, Kenilworth, Southampton) to explore why these interventions are (or are not) effective, in what ways, for whom and in what circumstances. See www.iconnect.ac.uk

Visions for the Role of Walking and Cycling 2008-2013

Led by the Institute for Transport Studies at Leeds University in collaboration with partners from the Universities of Oxford, Salford, East Anglia and Manchester, this project is exploring how the transport landscape might look in 2030 if a far greater proportion of journeys were made using human propulsion, and is drawing in modelling, narratives and storylines to help make the research more socially accessible.