# Deep carbon emission reductions in existing UK social housing: are they achievable, and how can they be funded?

Andrew Reeves
Institute of Energy and Sustainable Development
De Montfort University, United Kingdom
areeves@dmu.ac.uk

Simon Taylor
Institute of Energy and Sustainable Development
De Montfort University, United Kingdom
sctaylor@dmu.ac.uk

Paul Fleming
Institute of Energy and Sustainable Development
De Montfort University, United Kingdom
pfleming@dmu.ac.uk

## Keywords

domestic energy efficiency; existing social housing; carbon emission reduction; economic assessment; UK

## Abstract

As part of the UK's effort to combat climate change, deep reductions in carbon emissions will be required from existing social housing. The potentially high cost of the required stock refurbishment is a key barrier to the achievement of this goal. No assessments exist to date of the viability of achieving deep emission cuts whilst overcoming this financial barrier. For this study, this viability has been assessed for Peabody, a large housing association operating in London.

A model of energy use, carbon emissions and refurbishment costs has been developed for Peabody's existing stock. Various approaches to stock refurbishment up to 2030 were modelled, and outputs were assessed against four socio-economic scenarios, reflecting uncertainty about future fuel prices and efforts to mitigate climate change. Carbon emission reduction was assessed against the target set by the Greater London Authority (GLA) for 2025 for London in the London Climate Change Action Plan.

The results indicate that the GLA's target can only be achieved through extensive stock refurbishment and only then against a background of substantial efforts to reduce UK carbon emissions. Despite assumptions of considerable financial support for refurbishment in the scenarios studied, the required measures require a significant increase in net expenditure and are therefore not financially viable for Peabody without extra funding.

These findings point towards a future context where carbon emission reduction in housing is increasingly reliant on measures that may not provide net savings over the long term. The existence of a funding gap leads to the question of how it could be bridged. Two options for achieving this are explored: increasing rents or selling properties. The option of increasing rents is shown to have some potential in Peabody's case, as current rent levels are relatively low, but would require changes in Government policies on permitted rent increases.

## Introduction

Over the coming decades, the UK faces the considerable challenge of achieving deep cuts in carbon emissions from its existing housing stock, as part of the global effort to combat climate change. Social housing makes up around a fifth of UK homes, and social housing providers are likely to be at the forefront of efforts to comprehensively refurbish existing UK housing to achieve substantial reductions in carbon emissions. This process is still in its infancy and presents a number of challenges: reconciling emission reduction with a desire to preserve architectural heritage; applying new and emerging technologies; ensuring that affordable warmth is available to residents.

This research has sought to explore the viability of achieving deep carbon emission cuts (defined here as emission reductions of the order of 60% or beyond) for existing social housing. This was carried out through a case study focusing on one UK housing association, Peabody (formerly the Peabody Trust), that manages 18,000 homes in London. The carbon reduction target set by the Greater London Authority (GLA) of a 60% reduction in London emissions by 2025 relative to a 1990 baseline has been used to assess progress. The stock refurbishment measures that will be required to meet this goal for Peabody's existing stock have been assessed, alongside the financial viability of funding the work and the contextual influences on its viability. Based upon the conclusions arising from this work, implications for Government policy and the broader social housing sector are presented.

## Background

### THE CONTEXT OF LOW-CARBON REFURBISHMENT IN THE UK

The need for a substantial programme of refurbishment of the UK's existing housing stock to both mitigate climate change and reduce levels of fuel poverty is well-established amongst practitioners and researchers in the fields of housing and energy efficiency (Boardman et al. 2005a; Sustainable Development Commission 2006; UK Green Building Council 2008).

Despite this need, progress to date in carrying out this work has been slow. Government policy and grant funding is still largely focused on measures with low upfront costs and short payback periods such as cavity wall insulation and loft insulation. Installation rates for more costly carbon reduction measures, such as solid-wall insulation and micro-generation technologies, are some way below those required for a pathway towards deep emission cuts (WWF 2008). Comprehensive whole-house refurbishments are likely to be required to achieve deep emission cuts in the housing sector, but as of 2008, only several dozen homes had been identified in the UK as being refurbished to such a standard (Killip 2008). A long-term strategy for existing housing refurbishment has not been forthcoming from Government, contrasting sharply with the strategic steer given to new build housing (CLG Committee 2008).

Research on renovation of the existing UK housing stock has until recently focused on carbon emission reduction from the perspective of technical feasibility. Of the modelling exercises done so far for the UK housing stock, each has concluded that targets for emission reductions for 2050 can be achieved, both for targets of 60% and 80% (BRE 2005; Johnston et al. 2005; Boardman et al. 2005a; Boardman 2007; WWF 2008).

More recent research has incorporated recommendations for policymakers to achieve these emission reductions, such as mandating improvements to existing dwellings, developing capacity in industry and removing financial disincentives to refurbishment (Boardman 2007; Energy Saving Trust 2008; Killip 2008). In addition, a number of contextual factors that play an important role in achieving deep emission cuts have been identified, including decarbonisation of grid electricity, reduced demand for energy services and rapid take-up of carbon reduction technologies (Boardman 2007; Energy Saving Trust 2008).

To date there has been little research addressing the viability of achieving deep carbon reductions in particular housing sectors, such as the social housing sector. Existing research on deep emission cuts has also not assessed the financial viability of refurbishment approaches, due in part to the many uncertainties involved in predicting costs over a very long timescale (Hinnells 2005). The present research covers the period up to 2030, a timescale for which social landlords will typically plan for through their long term financial strategies. This shorter time horizon reduces uncertainties around costs, making it more appropriate to quantify the financial impacts of refurbishment.

### THE CASE OF UK SOCIAL HOUSING STOCK

The UK social housing sector exists to provide affordable housing, with provision being approximately equally split between local authorities and housing associations. It differs markedly from other housing sectors in that it is regulated and heavily influenced by Government policy. This is exemplified by the works currently ongoing to meet the Decent Homes standard in social housing stock, the need for new social homes to meet higher environmental standards than other new builds, and pressure from the regulator of housing associations, the Homes and Communities Agency (previously the Housing Corporation), to increase energy efficiency and reduce carbon emissions. However, Government policies to mandate strong action to reduce emissions in social housing, for example, by treating solid-walled homes or installing micro-generation, have not been forthcoming.

In this context, refurbishment to reduce carbon emissions has been largely restricted to low-cost measures (loft insulation, draught-proofing, etc.) and occasional grant-funded demonstration projects, such as European Union funded photovoltaic installations at Peabody. Without a compulsion to act and without sufficient funding support to make investments cost-neutral, the high installation costs have typically prevented many measures from being taken up widely by social landlords.

When stock refurbishment was made compulsory for social landlords through Decent Homes legislation, this led to some landlords, including Peabody, needing to sell homes to generate enough funds to carry out the improvements. Rent increases are typically not a viable strategy for many landlords in the current regulatory context, as rent restructuring legislation prohibits housing associations from raising rents above Government-prescribed levels.

## Methods

A case study method has been used for this research, focusing on one housing association, Peabody. Through working closely with one organisation, it has been possible to develop a detailed understanding of the contextual, regulatory and financial factors affecting the delivery of carbon reduction measures.

The research focuses on carbon emissions that result from direct and indirect energy use in the home, excluding issues such as transport or waste from the analysis. Only physical improvements to homes and changes to energy supply systems have been considered, as these are the primary responsibility of a social landlord. Measures to encourage behaviour change are therefore outside the scope of this research.

The effects of distinct approaches to stock refurbishment for Peabody's existing homes have been modelled up to the year 2030. The Peabody Energy Model (PEM) was developed for this research to meet this aim, quantifying energy use in the Peabody stock on an estate by estate basis, from the base year 2006 (the base year for the London Climate Change Action Plan) to 2030. It is assumed that Peabody's current planned work to meet the Decent Homes standard, which incorporates low-cost insulation measures, continues to 2010. From 2011, the impacts on carbon emissions and expenditure of various approaches to refurbishment were modelled. Four scenarios were used to specify the broader external context under which

**Table 1. Refurbishment approaches**

| Approach | Description |
|---|---|
| Base | After Decent Homes improvements are complete in 2010, the only improvements to the fabric of Peabody Homes that are relevant for this research are double-glazing installations, carried out when windows need to be replaced (so that an estimated 50% of homes needing replacement windows are treated by 2030). No changes are made to building services, except for existing boilers being replaced by new efficient models when due for replacement. |
| Fabric | From 2011, measures are applied in a single visit to each estate as required from a package consisting of: solid wall insulation; double-glazing; extractor fans; thermostatic radiator valves; heat meters and improved controls (for communally heated homes); replacement of storage heaters with gas boilers. Homes that cannot be externally insulated are insulated internally as they are vacated by residents from 2011 to 2030. |
| Communal | As for the Fabric approach, but estates are connected to district heating networks where a connection is available, and communal heating fed by gas-fired combined heat and power (CHP) is installed on other estates where feasible. |
| Renewables | As for the Communal approach, but solar thermal panels (4 $m^2$) are installed on suitable top floor flats and houses, and photovoltaic (PV) panels are installed on all remaining suitable roof space. |

refurbishment takes place, affecting model variables such as demand for energy and availability of funding for micro-generation technologies.

Average annual carbon dioxide emissions per dwelling are calculated for each estate from 2006 to 2030. These figures are used to calculate percentage reductions in emissions from 2006 to 2025 to assess progress against the GLA target. The emission reductions achieved for distinct types of Peabody stock are also assessed, so as to identify implications for the broader social housing sector. Annual net expenditure relating to refurbishment measures for Peabody is calculated for the period 2011 to 2030 to form a basis for an assessment of financial viability.

## REFURBISHMENT APPROACHES

Four approaches to refurbishment up to 2030 were initially considered (Table 1), based upon recommendations made for Peabody by the energy consultancy Rickaby Thompson Associates and in ongoing parallel PhD research by Dwyer (Rickaby Thompson Associates 2003; Dwyer 2007). The Base approach represents a continuation of current servicing regimes. Other approaches represent extra measures being carried out to improve the stock, with all one-off improvements being done by 2025, so that their impact on meeting the GLA target can be identified. These approaches have been designed specifically to be appropriate for Peabody stock, the majority of which is solid-walled, and much of which is in blocks in central London, making communal heating potentially economically viable. Many Peabody estates are in conservation areas, so it was assumed for these estates that due to concerns about maintaining their external appearance, external insulation or micro-generation measures could not be applied.

The impacts of modifying these approaches were also considered. This included the option of temporarily re-housing ("decanting") residents so that internal insulation could be installed, and of installing a different mix of technologies, including the potential use of ground or air source heat pumps and communal biomass boilers.

## MODELLING ENERGY USE AND CARBON DIOXIDE EMISSIONS

The PEM models energy use on a year by year and estate by estate basis for 189 Peabody estates, for the period 2006 to 2030. Carbon dioxide emissions are calculated based upon assumed demand for energy, the systems installed to provide energy services and assumptions for carbon intensity of supplied energy. It will not be possible to report each of the many assumptions made for the PEM in this short paper, but the key points will be summarised below. For more details see Reeves (2009).

Data on estates for the model were sourced from Peabody records where available. Data for average floor areas were only available for a fraction of estates, so floor areas were estimated using English House Condition Survey data for average UK and London floor areas, giving a good match to those estates where data were available. External wall areas were estimated using an equation from Boardman, Darby et al (2005b) and window areas were estimated based upon age of dwelling and floor area using equations from the UK Government's Standard Assessment Procedure (SAP) for energy rating of dwellings (BRE 2006a).

Domestic energy use is highly challenging to model accurately on an individual household level, due to the large variations in behaviour between householders, but aggregated models based on both building attributes and demographic assumptions have achieved results that match well with empirical data (ECI 2007; Natarajan and Levermore 2007a). Using this method of combining building-related and demographic assumptions, the PEM takes the BREDEM model as a starting point (BRE 2001), which estimates domestic energy demand as a function of floor area and number of residents and has been widely used in similar research.

Following the BREDEM method, energy demand was considered through five distinct categories: heat, hot water, lighting, cooking and (other) electricity. The BREDEM equations for electricity and cooking were modified to reflect changes in demand since 2001 based upon trends in per capita energy use (BERR 2008), so that electricity demand for 2006 was increased by 11% and demand for energy for cooking was reduced by 6%. Demand for lighting was calculated using the equation given in SAP 2005 (BRE 2006a), with a modification so that the energy

**Table 2. Conversion factors in 2006**

| Category | Conversion Factor (kg $CO_2$/kWh) | Source |
|---|---|---|
| Electricity | 0.527 | Defra (2007) |
| Gas | 0.206 | Defra (2007) |
| District Heating | 0.158 | Peabody |
| Electricity exports | 0.578 | BRE (2006a) |
| Biomass | 0 | Assumed |

saved by energy efficient lighting can increase as light emitting diodes come onto the market. Demand for hot water was estimated using a modified form of the original BREDEM equation based upon occupant data (DTI 2005). Demand for heat was assumed to be proportional to floor area for a given built form. Date of construction, type of dwelling (flat or house) and insulation levels determined the values used for annual demand for heat per square metre. Figures for average houses or flats with these attributes were taken from the Community Domestic Energy Model (CDEM), an area-based implementation of BREDEM developed at De Montfort University (Firth 2007).

It was assumed that the demand levels given by the equations apply equally to residents in Peabody stock, with the exception of electricity use, where there is evidence of lower electricity use for social housing residents (Brandon and Lewis 1999; BRE 2006b). This led to the assumption of demand being lower than that given in the modified BREDEM equation, with a 10% reduction being applied based upon Peabody experience on its BedZED estate.

Modelled energy use was converted into carbon dioxide emissions through conversion factors for each fuel. Conversion factors for the base year 2006 are given in Table 2. It was assumed that exported electricity displaces electricity from the marginal plant supplying the grid (coal and gas fired power stations), leading to a higher conversion factor than for grid imports. Biomass was assumed to be carbon neutral, as although there are clearly emissions associated with the transportation and processing of the fuel, these supply chain emissions are not considered for other conversion factors, and so for consistency, have not been considered for biomass. Beyond 2006, changes in emission factor were specified according to the four scenarios defined later in this paper.

### EMISSION REDUCTION TARGETS

Progress on carbon emission reduction was assessed against the GLA's target for London for 2025 (GLA 2007). Based upon the carbon budget given in the GLA report for existing housing emissions in 2025, and assuming further emissions arising out of the construction of planned new housing up to that date, the GLA target translates into an average reduction of existing housing emissions in London of 57.4% by 2025 (Reeves 2009).

This target is broadly commensurate with the target of 80% reductions called for by the UK Government (DECC 2008) and investigated in recent research on housing refurbishment (Boardman 2007; WWF 2008). In the light of increasing evidence that to minimise the risks of serious climate impacts, greater reductions than those called for by existing targets may be required over a shorter timescale (Anderson and Bows 2008; Public Interest Research Centre 2008), the GLA target is put forward as a minimum level of action from the perspective of climate change mitigation.

### MODELLING ENERGY COSTS

Energy costs, namely costs for gas, electricity and heat from communal heating installations, were incorporated in the model to identify the financial impacts of refurbishment approaches for Peabody and its residents. Base costs were based upon the standard gas and electricity tariffs for London for British Gas and EDF energy respectively, the suppliers of each service in the London area prior to deregulation. Future energy costs were dependent on the scenarios defined in Table 3 and are given in Table 4.

### MODELLING THE FINANCIAL IMPACTS OF REFURBISHMENT

The financial implications of refurbishment were identified by contrasting the expenditure required for each refurbishment approach with that for the Base approach. Annual net cash flows throughout the period 2011 to 2030 were calculated, incorporating both capital spending on measures, sales of energy from Peabody to residents, income from exporting electricity to the grid and income from Government initiatives to support the generation of renewable energy.

To take into account that the costs and benefits over the timescale under consideration are typically given greater weight the earlier they occur (HM Treasury 2007), the net present value (NPV) of each refurbishment approach was calculated to enable comparison between approaches. NPV is calculated by applying a discount rate to cash inflows and outflows over the assessment period, and summing the results.

A positive NPV is an indication that an investment is financially beneficial, whilst a negative NPV indicates the lack of a financial case for an investment. For investments considered as part of this research, the NPV figures given for each refurbishment approach are *relative to the Base approach* (so, by definition, the Base approach has an NPV of £0). They therefore represent the extra monetary value that is generated by a particular more-extensive refurbishment approach (if NPV is positive), or the resulting reduction in value (if NPV is negative).

NPV is calculated for both Peabody and its residents considered as a whole (referred to from this point as *NPV*), and for Peabody considered alone (referred to as *Peabody NPV*). The former definition identifies the most cost-effective measures overall for carbon emission reduction. By considering landlord and tenants as a whole, it is unaffected by the split incentives that exist for the two parties, whereby landlord investments can lead to savings for residents. A positive NPV in this case indicates a "social case" for the refurbishment approach, indicating that Peabody and its residents are better off as a whole by that

**Table 3. Scenario descriptions**

| | |
|---|---|
| Keeping the Lights On (KLO)<br>Low fuel prices, weak action on climate change. | Concerns about energy security over-ride action on climate change. Assumed: continued economic growth, a continuation of present-day trends in domestic energy demand, and a relatively low increase in grid electricity provided by renewables. |
| Sustainable Development (SD)<br>Low fuel prices, strong action on climate change. | Strong measures to mitigate climate change in the context of a growing economy. Assumed: substantial grant funding for refurbishment, significant increases in renewables supplying the grid and reduced domestic energy demand. |
| Breaking Down (BD)<br>High fuel prices, weak action on climate change. | Strong focus on energy security but with very high fuel prices leading to a series of deep recessions. Assumed: marginal reduction in domestic energy demand due to high prices, low use of grid renewables and low Government support for domestic energy saving measures. |
| Power Down (PD)<br>High fuel prices, strong action on climate change. | Strong efforts to reduce carbon emissions with a focus on reducing energy demand, which partially mitigates the impact of high fuel prices on fuel bills and the economy. Assumed: strong financial support for refurbishment and increases in renewables supplying the grid. |

**Table 4. Scenario assumptions**

| Issue | Scenario Assumptions |
|---|---|
| Carbon intensity of grid electricity | Declines more rapidly in PD and SD scenarios than KLO and BD. By 2025, falls by 29% relative to 2006 levels for KLO/BD, and by 51% for SD/PD. By 2030, reductions are 39% and 68% respectively. |
| Demand for energy services | KLO continues current trends, with electricity demand increasing and other uses stabilising. Environmental concerns lead to reductions for SD and PD. High fuel prices lead to reductions for PD and BD.<br>Changes to 2030 for electricity: +48% (KLO); -7% (SD); -20% (PD); +2% (BD).<br>Changes to 2030 for other energy use: +0% (KLO); -11% (SD); -23% (PD); -13% (BD). |
| Grant funding | Greater support in PD and SD scenarios. A fraction of estates in Low Carbon Zones[1] receive refurbishment at no cost to Peabody (21% of estates in SD, 30% in PD). On other estates there is grant funding for insulation (5% of costs for KLO, 20% for SD, 30% for PD, 10% for BD) and renewables (5% of costs for KLO and BD, 30% for SD and 20% for PD). |
| Support for micro-generation | Renewable heat obligation brought in for PD and SD. Feed-in tariffs brought in to support electricity generation in SD. Renewables obligation remains in other scenarios. |
| Discount rate | Relates to assumed economic growth rate. The Treasury recommended rate of 3.5% is assumed for KLO and SD. Lower assumed growth rates lead to assumptions of 2% for PD and 1.5% for BD. |
| Fuel prices | Increases are greater in PD and BD. PD and SD scenarios have relatively higher increases for electricity due to strong investment in renewables. Gas prices in 2030 relative to 2008 levels are greater by 24% (KLO), 39% (SD), 72% (PD), 113% (BD). Electricity prices are greater by 24% (KLO), 72% (SD), 113% (PD), 92% (BD). |

*1. Low Carbon Zones are a delivery mechanism for housing stock refurbishment put forward by Boardman (2007)*

approach. The latter definition is the more traditional application of NPV, used to measure whether it is in the financial interests of Peabody as a business to make a particular set of investments. A positive NPV in this case indicates a "business case" for refurbishment. A negative NPV would indicate that further funding is required to make a refurbishment approach financially viable for Peabody.

Although the NPV method may not be commonly used in practice by social landlords to make stock refurbishment decisions, which are subject to many other non-financial influences, it is employed here as the most effective means of capturing the long-term financial impact of stock refurbishment approaches.

The NPV calculations carried out for the Peabody model are atypical, as many investments are modelled which require significant capital expenditure, but are only installed for a fraction of their lifetime before the end of the 2011–2030 assessment period. If only expenditure and income during the assessment period was considered, this would tend to generate a bias against strategies involving capital-intensive measures such as photovoltaic panels, which would continue accruing savings beyond the 2030 horizon. To overcome this effect, a terminal value is calculated for all measures, representing the fraction of the initial capital cost that remains "unused" by 2030, based upon the measure's assumed lifespan. The terminal value is then considered as an income in 2030 when NPV is calculated.

The capital and maintenance costs for each measure considered were based upon Peabody experience to date where available or from literature on housing renovation where not, and include full installation costs and VAT at 17.5% (the temporary cut in UK VAT to a rate of 15% will have expired prior to 2011, the first year of the period when costs are studied in this research).

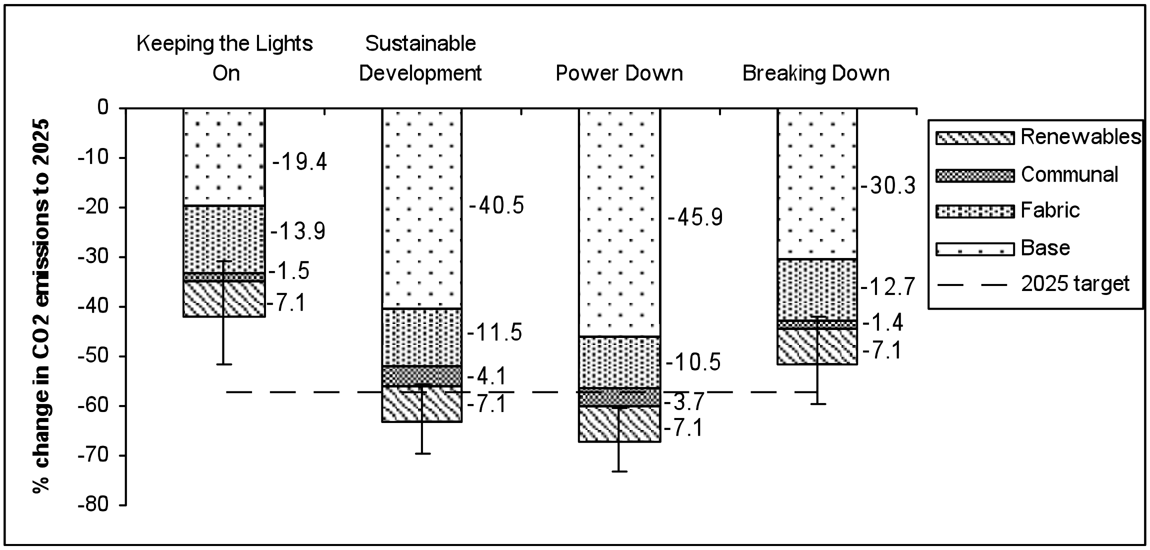

*Figure 1. Carbon emission reductions by refurbishment approach*

### SCENARIOS

Scenarios were used to specify the broad external context in the period up to 2030. Assumptions for each scenario were made to quantify the impact on model results. Four scenarios were defined by identifying key factors that are both highly significant for model results, relatively independent and which have significant uncertainty about their outcome (Schwartz 1991).

Existing research that addresses factors affecting future domestic carbon emissions has identified a number of significant issues. These include: levels of domestic energy demand; availability of heat and electricity from renewable sources; take-up of energy saving technologies; technological innovation; economic growth; fuel costs (BRE 2005; Johnston et al. 2005; Tyndall Centre 2005; Boardman et al. 2005a).

Bringing together the issues identified above, the two key issues used to define scenarios were the extent of action to mitigate climate change in the UK and the cost of fuel. Four scenarios were then specified taking into account the inter-relationships between the defining issues and other relevant issues, including those listed in Table 3. The key implications of these scenarios for model assumptions are given in Table 4.

## Results

### CARBON EMISSIONS

The emission reductions achieved by 2025 for each refurbishment approach under the four considered scenarios are shown in Figure 1. The key result is that the 2025 target can only be achieved in the two scenarios defined by strong action on climate change. For the KLO and BD scenarios, even the most extensive approach to refurbishment considered is insufficient to meet the GLA's carbon reduction target.

In both scenarios where the target is achieved, Peabody's current planned approach to refurbishment (the Base approach) is not sufficient to bring this about. For the SD scenario, only the Renewables approach is sufficient. The PD scenario, which has greater assumed reductions in energy demand, can achieve the target through the Communal or Renewables approaches, and is close to doing so through fabric improvements alone.

Figure 1 illustrates the emission reductions achieved relative to the 2025 target. The error bars on the graph indicate the results of sensitivity analysis on the model outputs for the Renewables approach, illustrating the maximum and minimum reductions achieved where model variables are changed to reflect uncertainty in their values. The full results of this analysis (see Reeves 2009) indicate that the carbon intensity of grid electricity and resident demand for energy are the two variables having the greatest impact on results.

To take into account the impact of this uncertainty, it is suggested that the target can be met with a *good degree of confidence* for a particular scenario if it is met even for the lowest possible result identified by changing model variables through sensitivity analysis. By this definition, only the Renewables approach in the PD scenario can be said to allow the 2025 target to be met with a good degree of confidence.

### FINANCIAL IMPACTS OF REFURBISHMENT

The results indicate that for each scenario modelled, the addition of each refurbishment package leads to a reduction in NPV (Figure 2). This result is particularly pronounced where solar thermal and solar PV are installed. This result contrasts with the positive NPV typically associated with measures such as cavity wall insulation or draught-proofing, due to the payback on the initial investment achieved within a small number of years.

For the Fabric approach, which is the only one delivering significant fuel bill savings to residents, this result illustrates that overall savings for residents are outweighed by the increased costs of refurbishment. If rents were raised to cover these refurbishment costs, residents would therefore be worse off overall in each scenario.

The NPV values are significantly greater in the SD and PD scenarios due to the assumptions of considerable financial support for refurbishment, but this is not sufficient to make any approach financially attractive.

The results for Peabody NPV (Figure 3) show a similar pattern, with the only significant difference being the reduced NPV for the Fabric approach (as the financial benefits for resi-

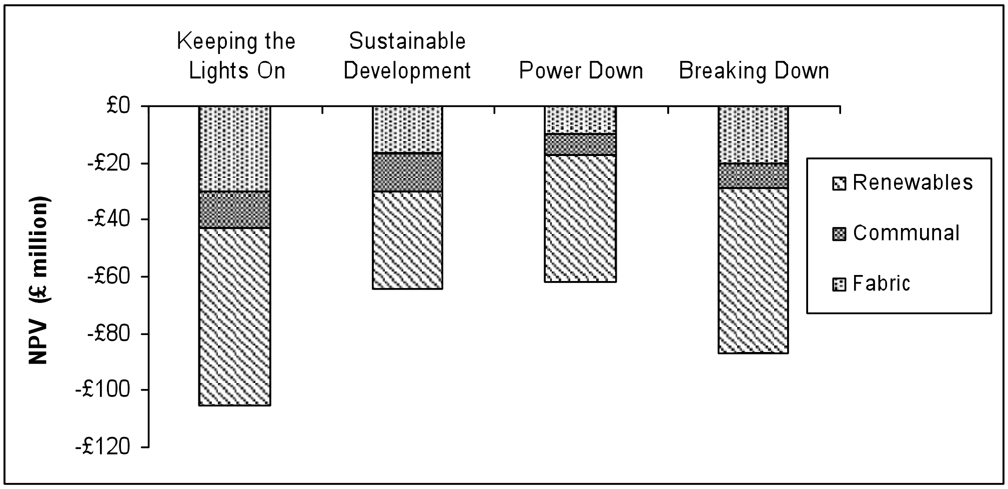

*Figure 2. NPV by refurbishment approach*

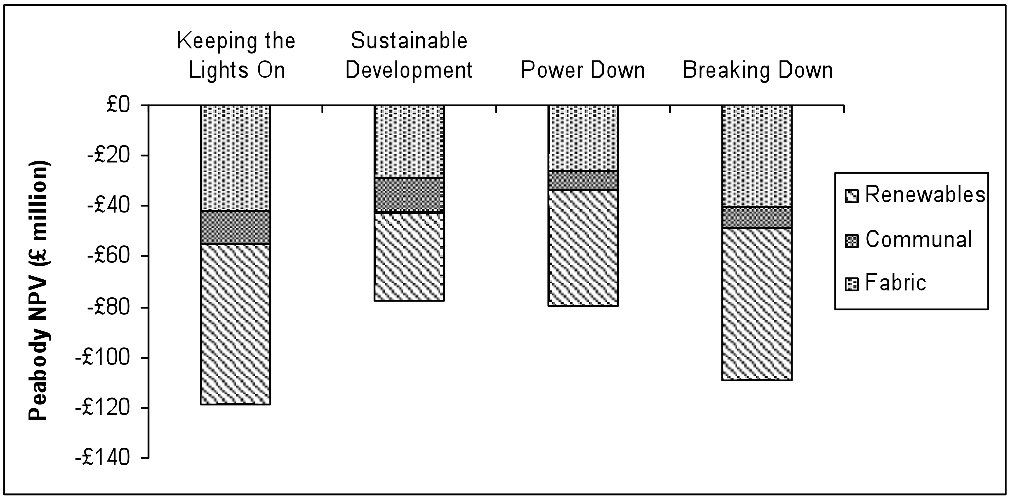

*Figure 3. Peabody NPV by refurbishment approach*

dents are no longer taken into account). The finding that every approach has a negative impact on Peabody NPV indicates that of those considered, the current approach to refurbishment is the least cost option for Peabody in each scenario over the long term.

### COST-EFFECTIVENESS OF MEASURES AT REDUCING EMISSIONS

The cost-effectiveness of each measure considered at reducing carbon emissions was assessed, so that this information could be used to identify the most cost-effective approaches to meet the GLA target for each scenario. This was achieved by calculating the change in NPV and Peabody NPV brought about through each measure for each tonne of $CO_2$ saved in the period 2011 to 2030.

The results (Table 5) indicate that none of the measures considered have a positive NPV from Peabody's perspective in any of the scenarios considered. The cost-effectiveness varies significantly across scenarios due to factors such as the changes in grant funding for measures, changes in fuel costs and demand for energy. The most cost-effective measures include fabric improvements, biomass boilers and district heating. The results for CHP are subject to a significant degree of uncertainty around its installation costs, as identified by sensitivity analysis. If the cost of installation is at the low-end of the range of costs considered, CHP could potentially be the most cost-effective carbon reduction measure. For solar PV, NPV and Peabody NPV are identical in each case as it is assumed that all electricity generated is sold to the grid, so residents do not benefit financially from its installation.

Considering the NPV for Peabody and its residents as a whole, measures that reduce resident fuel costs have a higher NPV, so that fabric measures in void dwellings (comprising internal insulation and ventilation) have an NPV close to zero in the PD and BD scenarios. Conversely, installations of heat pumps have a significantly more negative NPV, due to resident fuel bills increasing as a result of a switch from gas to more-expensive electricity as a fuel.

### MEETING THE GLA'S 2025 TARGET

Taking into account the availability of other carbon reduction measures, the original approaches to refurbishment considered were modified to identify a variety of approaches that meet the GLA target. Where measures were used in combination, the results on the cost-effectiveness of emission reduction were

**Table 5. NPV of measures per tonne of $CO_2$ saved**

| | KLO | | SD | | PD | | BD | |
|---|---|---|---|---|---|---|---|---|
| Measure/Approach | NPV | Peabody NPV | NPV | Peabody NPV | NPV | Peabody NPV | NPV | Peabody NPV |
| Fabric | -£250 | -£350 | -£154 | -£271 | -£100 | -£258 | -£184 | -£361 |
| Fabric with decanting (relative to Fabric) | -£725 | -£832 | -£450 | -£567 | -£218 | -£373 | -£674 | -£864 |
| Fabric measures in voids | -£109 | -£214 | -£77 | -£190 | £8 | -£148 | -£7 | -£200 |
| CHP | -£1,081 | -£1,097 | -£1,553 | -£1,594 | -£1,098 | -£1,154 | -£740 | -£761 |
| District Heating | -£450 | -£460 | -£230 | -£236 | -£102 | -£111 | -£337 | -£351 |
| Solar PV | -£1,017 | -£1,017 | -£580 | -£580 | -£779 | -£779 | -£949 | -£949 |
| Solar Thermal | -£884 | -£984 | -£461 | -£565 | -£496 | -£636 | -£803 | -£984 |
| GSHPs | -£3,097 | -£2,604 | -£674 | -£398 | -£710 | -£299 | -£3,642 | -£2,822 |
| ASHPs | N/A[1] | N/A[1] | -£1,687 | -£782 | -£2,491 | -£1,087 | N/A[1] | N/A[1] |
| Biomass Boilers | -£280 | -£284 | -£269 | -£276 | -£238 | -£248 | -£265 | -£270 |

[1] *"N/A" indicates that the approach leads to a net increase in emissions.*

used to specify approaches that could meet the target as cost-effectively as possible. This led to a preference for achieving emission cuts by extending the Fabric approach to incorporate decanting of residents so that internal insulation could be fitted, rather than investing in micro-generation technologies. A preference for more extensive insulation measures also brings with it the benefit of reducing resident fuel bills and potentially alleviating fuel poverty.

Considering the issue of likelihood that an approach is successful given the uncertainties in the model, a *Good Confidence* approach was also devised. This is the approach with the greatest NPV for which the 2025 target is still met even if demand for energy (the most significant factor identified in the sensitivity analysis) is at the upper bound considered for this scenario. A *Maximum* approach for each scenario combined all measures under consideration that led to emission reductions by 2025. The resultant approaches for each scenario are given below.

### Keeping the Lights On

For this scenario, no combination of measures that would allow the GLA's target to be met was possible.

### Sustainable Development

Six approaches are put forward that have potential to meet the 2025 target (Table 6). The Good Confidence approach relies on decanting residents so that homes can be internally insulated, and installing district heating, biomass boilers and solar thermal to a significant degree. This approach has an NPV for Peabody of minus £77 million (86 million Euro).

### Power Down

The Power Down scenario is the most successful of the scenarios modelled in terms of emission reductions, due to the combination of low energy demand and increased availability of low carbon energy. As a result, a number of distinct approaches could be employed to meet the 2025 target (Table 7). The Good Confidence approach has an NPV for Peabody of minus £54 million (60 million Euro).

### Breaking Down

For this scenario, the GLA target could only be achieved through a "Maximum" approach, comprising the Fabric approach (with decanting), district heating, biomass boilers, solar PV and solar thermal. This achieved emission reductions of 60%, with an NPV of minus £120 million (minus 134 million Euro) and a Peabody NPV of minus £150 million (minus 168 million Euro). Given the uncertainties in the model, it is some way short of meeting the target with a good level of confidence.

## IMPACTS OF STOCK TYPE

Peabody stock differs markedly in its makeup from other social housing stock and other housing in London (Table 8). The emission reductions achieved in distinct types of Peabody housing were assessed in order to identify the implications of this research for the broader housing sector in the UK. Peabody stock was broken up into five categories. *Electric* estates are those having mostly (or entirely) electric heating. All but one of these estates were built in the last 20 years. *Scattered* estates consist of street properties with a greatly varying age profile. The remaining estates were divided up according to their date of construction: *Modern* estates are those built after 1991; *Recent* estates are those built between 1951 and 1991; *Old* estates are those built before 1951, and are typically solid-walled blocks of flats.

The emission reductions achieved for different stock types are illustrated for the Good Confidence approach to meeting the 2025 target in the PD scenario (Table 9). Prior to refurbishment, emissions vary significantly between Peabody dwelling types, and are all below the UK average, as is typical for social housing. After refurbishment, emissions per resident are broadly similar across all stock types, between 0.6 and 0.7 tonnes per annum. The greatest percentage reductions are achieved on older estates and estates with electric heating — those which currently have higher emissions and the greatest potential for reductions.

**Table 6. Approaches to meet the 2025 target for the SD scenario**

| Approach | Description | $CO_2$ Emission Reductions to 2025 | NPV | Peabody NPV |
|---|---|---|---|---|
| Biomass | Fabric; District Heating; Biomass boilers | 59% | -£30 million | -£43 million |
| Decanting | Fabric with decanting; District Heating | 60% | -£46 million | -£64 million |
| Solar PV | Fabric; District Heating; Solar PV | 62% | -£56 million | -£68 million |
| Renewables | Fabric; CHP; District Heating; Solar PV; Solar Thermal | 63% | -£64 million | -£78 million |
| Good Confidence | Fabric with decanting; District Heating; Solar Thermal; Biomass boilers | 65% | -£58 million | -£77 million |
| Maximum | Fabric with decanting; Biomass boilers; District Heating; Solar PV; Solar Thermal; Ground Source Heat Pumps; Air Source Heat Pumps; Retained Storage Heaters | 73% | -£99 million | -£111 million |

**Table 7. Approaches to meet the 2025 target for the PD scenario**

| Approach | Description | $CO_2$ Emission Reductions | NPV | Peabody NPV |
|---|---|---|---|---|
| Solar Thermal | Fabric; Solar Thermal | 58% | -£17 million | -£35 million |
| Heat pumps | Fabric; GSHPs | 59% | -£22 million | -£31 million |
| District Heating | Fabric; District Heating; | 60% | -£13 million | -£29 million |
| Communal | Fabric; CHP; District Heating | 60% | -£17 million | -£34 million |
| Biomass | Fabric; Biomass boilers | 61% | -£19 million | -£35 million |
| Decanting | Fabric with decanting; | 61% | -£22 million | -£46 million |
| Solar PV | Fabric; Solar PV | 63% | -£54 million | -£70 million |
| Good Confidence | Fabric with decanting; District Heating; Biomass boilers | 67% | -£30 million | -£54 million |
| Renewables | Fabric; CHP; District Heating; Solar PV; Solar Thermal | 67% | -£62 million | -£80 million |
| Maximum | Fabric with decanting; Biomass boilers; District Heating;Solar PV; Solar Thermal; GSHPs; ASHPs; Retained Storage Heaters | 76% | -£87 million | -£103 million |

### MEETING THE FUNDING GAP

The refurbishment approaches that allow the GLA target to be met have a negative NPV for Peabody of between minus £35 million and minus £111 million (39 million Euro to 124 million Euro). The two Good Confidence approaches have Peabody NPVs of £77 million and £54 million for the SD and PD scenarios respectively. Although there is significant uncertainty around any estimates of refurbishment costs, these results do point towards a significant funding gap.

Bridging a gap of this scale using existing internal resources is likely to be challenging for any housing association. Given the recent efforts within the sector to achieve substantial efficiency savings (Housing Corporation 2006), making significant additional funding available without cutting back on existing planned expenditure is likely to be extremely challenging.

If a social landlord cannot fund increased refurbishment through existing internal resources, then two principal options remain to secure additional funds - increasing rents or disposing of properties. The implications of funding refurbishment through either of these two methods are explored here.

Rent increases of 0.5% per year beyond inflation (plus an annual £2 increase on weekly rent levels) are already planned for Peabody properties for the foreseeable future. This is the maximum increase currently permitted by Government, and is in place to enable Peabody homes (which currently have relatively low rents for London social housing) to move towards target rents set by Government.

Where sales of Peabody stock are considered, it is assumed for simplicity that units are sold prior to 2011. The number of Peabody dwellings requiring refurbishment and Peabody's rental income beyond that date are reduced accordingly. It is assumed that £210,000 is generated per unit sold, based upon current Peabody practice.

The results for the SD and PD scenarios, for which the GLA's target could be achieved, indicate that annual rent increases of between 0.2% and 1% would be required, or stock sales of between 210 and 730 homes (Tables 10 and 11). To have a good level of confidence of meeting the GLA target, as defined above, would require annual rent increases of 0.7% for the SD scenario or 0.4% in the PD scenario. As noted above, the investments assessed in this research do not lead to overall savings, so these rent increases would leave residents worse off financially overall.

**Table 8. Characteristics of Peabody stock relative to other social housing and housing in London**

| | % homes built prior to 1945 | % homes flats | Breakdown of non-flats | Source |
|---|---|---|---|---|
| Peabody | 51% | 82% | Remaining 18% mostly terraced or semi-detached | Peabody |
| All housing associations | 19% | 42% | 48% terraced or semi-detached, 10% detached | CLG (2008) |
| London | 58% | 45% | 33% terraced, 22% semis or detached | CLG (2006) |
| London social housing | 31% | 74% | 20% terraced, 6% semis or detached | CLG (2006) |

**Table 9. Emissions and emission reductions by stock type: PD scenario, Good Confidence approach**

| Stock Type (and % of stock) | 2006 emissions per home per annum (tonnes) | 2006 annual emissions per resident (tonnes) | Emission reductions to 2025 (PD scenario) | 2025 annual emissions per resident (tonnes) |
|---|---|---|---|---|
| Modern (14%) | 2.5 | 1.4 | 48% | 0.7 |
| Recent (14%) | 2.8 | 1.4 | 57% | 0.6 |
| Old (51%) | 3.7 | 2.2 | 74% | 0.6 |
| Electric (3%) | 4.0 | 2.4 | 70% | 0.7 |
| Scattered (18%) | 4.8 | 2.0 | 63% | 0.7 |
| Peabody Average | 3.6 | 1.8 | 67% | 0.6 |
| UK Average | 6.1 | 2.7 | N/A | N/A |

**Table 10. SD implications of meeting funding gap**

| | Biomass | Decanting | Solar PV | Renewables | Good Confidence | Maximum |
|---|---|---|---|---|---|---|
| Rent Increase | 0.4% | 0.6% | 0.6% | 0.7% | 0.7% | 0.9% |
| Stock Sales (no. units) | 290 | 430 | 460 | 520 | 520 | 730 |

**Table 11. PD implications of meeting funding gap**

| | Solar Thermal | Heat Pumps | District Heating | Communal | Biomass |
|---|---|---|---|---|---|
| Rent Increase | 0.3% | 0.2% | 0.2% | 0.3% | 0.3% |
| Stock Sales (no. units) | 250 | 220 | 210 | 240 | 250 |
| | Decanting | Solar PV | Good Confidence | Renewables | Maximum |
| Rent Increase | 0.3% | 0.5% | 0.4% | 0.6% | 0.7% |
| Stock Sales (no. units) | 330 | 500 | 390 | 560 | 720 |

## Discussion and Conclusions

### CARBON EMISSION REDUCTION

The results indicate that the GLA's 2025 target can be met for Peabody stock, through a combination of stock improvement measures and broader contextual change. A key finding is that even if Peabody were to use every technology considered to the greatest possible extent on its stock, there is no guarantee that this would lead to the GLA target being met. Significant changes in external factors are also necessary, with two critical factors being a reduction in resident demand for energy and the availability of low carbon energy (grid electricity or district heating). These conclusions echo findings in previous analysis (GLA 2007; Energy Saving Trust 2008), and are likely to apply equally to other social landlords.

If beneficial external conditions are in place, as they are for the SD and PD scenarios, the GLA target can be met, and the extent of refurbishment required depends on the extent of emission reductions already achieved by external factors. For the two successful scenarios considered is this research, this implies insulating all solid-walled estates (with residents being decanted on estates in conservation areas to achieve this), connecting up to 25% of estates to district heating networks and installing either communal biomass boilers or solar microgeneration technologies.

This represents a radical change in the current approach to refurbishment for Peabody, as it would for other social landlords with similar stock. However this scale of refurbishment is consistent with findings in previous research on achieving deep emission cuts in UK housing stock, where the most extensive deployment of technical measures coupled with an assumed supportive context has been found to be necessary to meet $CO_2$ reduction targets (BRE 2005; Boardman et al. 2005a; Boardman 2007; Natarajan and Levermore 2007b; Energy Saving Trust 2008; WWF 2008).

A more rapid emission reduction pathway may still be required for Peabody stock. This could be due to social housing playing a leading role in housing refurbishment, greater emission reductions being required from currently inefficient homes, or to Government policy requiring steeper reductions in UK emissions. If achieved through the technical measures considered here, this would imply much greater use of micro-generation and significantly increased expenditure. To illustrate this, the Maximum approach in the PD scenario achieves an 85% reduction by 2030 and has an NPV for Peabody of minus £103 million (minus 115 million Euro).

### BRIDGING THE FUNDING GAP

The results indicate that measures to meet the GLA target in the PD and SD scenarios could be funded by rent increases of up to 1% a year. To give these figures some context, the National Housing Federation, a body which represents English housing associations, has called for Government legislation on rent increases to be changed, permitting increases of 1% a year beyond inflation rather than the current 0.5% a year (National Housing Federation 2007). This further 0.5% increase would enable the Good Confidence approach to be funded in the Power Down scenario. However, it should be noted that this increase was called for as it was seen as necessary to fund further construction of new housing, rather than to fund carbon reduction refurbishment (ibid). There would therefore be competing demands on any increased rental income, and a potential need to increase rents beyond the figures given here if both goals were to be met. A strategy based on rent increases would also potentially conflict with the core goal of social landlords of providing affordable housing.

Rent increases could however be a viable funding method in Peabody's case, as existing rents are lower than average social rents in London, and some way below Government-set target rents for Peabody stock. Faster convergence towards target rents for Peabody could potentially generate enough extra income to fund the more-extensive refurbishment options considered in this research, without necessarily placing too great a burden on residents.

If the option of rent increases remains unavailable to social landlords, sales of stock would be the principal remaining strategy to fund refurbishment to reduce emissions. In Peabody's case this method would require the disposal of several hundred dwellings if used alone, a significant fraction of their total stock. Due to the reduction in the availability of social housing that this strategy would bring about, it is doubtful that social landlords would choose to pursue this funding strategy, unless action to refurbish existing housing was mandated by Government.

### IMPLICATIONS ARISING FROM THIS RESEARCH

The model results indicate the need for a substantial deployment of carbon reduction measures to achieve deep cuts in carbon emissions, even in a context of demand reduction and significant grid decarbonisation. The cost assumptions used for this research imply that if rent increases were used to fund carbon reduction measures, they would outweigh the fuel bill savings, leaving residents worse off overall. This situation is one that contrasts sharply with the context of carbon reduction refurbishment over previous decades, where improvements have typically led to fuel bill savings over the long term.

In this context, comprehensive action by social landlords is unlikely unless mandated by Government. Changing Government regulations so that social landlords could increase rents to offset their investment costs would help landlords to fund refurbishment, but would still be insufficient in itself to make refurbishment affordable in many cases.

If the task of carrying out comprehensive carbon reduction refurbishment is taken up by social landlords, either by choice or by compulsion, this would bring with it a significant shift in their responsibilities towards their stock. The present obligation to maintain the good condition of their stock would be extended to incorporate a responsibility to actively intervene to comprehensively reduce stock emissions. This research implies that this would bring with it increased costs that the current funding model for social landlords is unlikely to be geared up to deliver. This raises an important question of where this increased funding should come from. Possible sources are the tenants themselves (through increased rents), the taxpayer (through increased Government grants) or through selling off social housing stock.

The results for different types of Peabody stock can be used to identify some implications for the broader social housing sector. The relative difficulty in achieving emission reductions in more modern stock, which is more typical of the broader housing association sector, implies that greater reductions need to be achieved in older, less-efficient homes to offset this. This could imply that landlords with older stock such as Peabody should look to achieve reductions beyond any given percentage target applied to the housing sector. The results of this research imply that this would necessitate a greater application of micro-generation technologies for all types of dwelling, deepening the challenge of funding refurbishment.

This discussion should also be seen as part of the broader question of what the most desirable strategies for mitigating climate change are for the UK as a whole. If a significant application of micro-generation is necessary to achieve targets on-site for existing housing, concerns about cost-effectiveness could lead to a preference for achieving further reductions off-site, through increased decarbonisation of the grid. Thinking more broadly still from a cost-effectiveness perspective, any extra expenditure involved in improving existing housing should be compared to the costs of achieving emission cuts in other sectors of the economy, particularly if Government expenditure is to be justified. It is important to note though that emission reduction measures will often bring about other social benefits, and the alleviation of fuel poverty that can result from insulation measures is a strong argument in favour of a focus on existing housing.

## Glossary

| | |
|---|---|
| ASHP: | Air Source Heat Pump |
| BD: | Breaking Down scenario |
| CHP: | Combined Heat and Power |
| $CO_2$: | Carbon dioxide |
| GLA: | Greater London Authority |
| GSHP: | Ground Source Heat Pump |
| KLO: | Keeping the Lights On scenario |

| | |
|---|---|
| NPV: | Net Present Value |
| PD: | Power Down scenario |
| PEM: | Peabody Energy Model |
| PV: | Photovoltaics |
| SD: | Sustainable Development scenario |

## References

Anderson, K. and A. Bows (2008). "Reframing the climate change challenge in light of post-2000 emission trends." Philosophical Transactions of the Royal Society 366(1882): 3863-3882.

BERR. (2008). "Energy Consumption in the United Kingdom: Domestic Data Tables." Retrieved 16/01/09, from http://www.berr.gov.uk/files/file47214.xls.

Boardman, B. (2007). Home Truths. Oxford, Environmental Change Institute.

Boardman, B., et al. (2005a). 40% House Report. Oxford, Environmental Change Institute.

Boardman, B., et al. (2005b). 40% House project Background Material A: Model methodology. Oxford, Environmental Change Institute.

Brandon, G. and A. Lewis (1999). "Reducing household energy consumption: a qualitative and quantitative field study." Journal of Environmental Psychology 19(1): 75-85.

BRE (2005). Reducing Carbon Emissions from the UK Housing Stock. Garston, Watford, BRE.

BRE (2006a). SAP 2005: The Government's Standard Assessment Procedure for Energy Rating of Dwellings. Garston, Watford, BRE.

BRE (2006b). Domestic Energy Fact File 2006. Garston, Watford, BRE.

CLG. (2006). "English House Condition Survey - 2003 Regional Report " Retrieved 16/01/09, from http://www.communities.gov.uk/archived/publications/housing/englishhousecondition6.

CLG. (2008). "English House Condition Survey - Stock Profile." Retrieved 16/01/09, from http://www.communities.gov.uk/housing/housingresearch/housingsurveys/englishhousecondition/ehcsdatasupporting/ehcsstandardtables/stockprofile/.

CLG Committee (2008). Existing Housing and Climate Change. London, TSO.

DECC. (2008). "UK leads world with commitment to cut emissions by 80% by 2050." Retrieved 16/01/09, from http://nds.coi.gov.uk/environment/fullDetail.asp?ReleaseID=381477&NewsAreaID=2&NavigatedFromDepartment=False.

Defra (2007). Guidelines to Defra's GHG conversion factors for company reporting. London, Department for the Environment and Rural Affairs.

DTI (2005). Estimates of hot water consumption from the 1998 EFUS - implications for the modelling of fuel poverty in England. London, Department of Trade and Industry

Dwyer, S. (2007). Personal Communication.

ECI. (2007). "Reducing the environmental impact of housing: Final report, appendix D - Energy Model." Retrieved 16/01/09, from http://www.rcep.org.uk/urban/report/eci-appd_energy_model_revised.pdf.

Energy Saving Trust (2008). Towards a long-term strategy for reducing carbon dioxide emissions from our housing stock. London, Energy Saving Trust.

Firth, S. (2007). Personal Communication.

GLA (2007). Action today to protect tomorrow: the Mayor's climate change action plan, Greater London Authority, London.

Hinnells, M. (2005). The cost of a 60% cut in $CO_2$ emissions from homes: what do experience curves tell us? BIEE conference, Oxford.

HM Treasury (2007). Green Book. London, HM Treasury.

Housing Corporation (2006). Corporate Plan. London, Housing Corporation.

Johnston, D., et al. (2005). "An exploration of the technical feasibility of achieving $CO_2$ emission reductions in excess of 60% within the UK housing stock by the year 2050." Energy Policy 33(13): 1643.

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

Natarajan, S. and G. J. Levermore (2007a). "Predicting future UK housing stock and carbon emissions." Energy Policy 35(11): 5719-5727.

Natarajan, S. and G. J. Levermore (2007b). "Domestic futures--Which way to a low-carbon housing stock?" Energy Policy 35(11): 5728-5736.

National Housing Federation. (2007). "Federation Chair Throws Down the Gauntlet to Government." from http://www.housing.org.uk/default.aspx?tabid=232&mid=1150&ctl=Details&ArticleID=653.

Public Interest Research Centre. (2008). "Climate Safety." Retrieved 16/01/09, from http://climatesafety.org/wp-content/uploads/climatesafety.pdf.

Reeves, A. (2009). "Towards a low-carbon Peabody." London, Peabody. https://www.peabody.org.uk/about-us/corporate-information/policies-and-strategies.aspx.

Rickaby Thompson Associates (2003). Strategic Heating Review. Milton Keynes, Rickaby Thompson Associates.

Schwartz, P. (1991). The Art of the Long View. New York, John Wiley & Sons.

Sustainable Development Commission (2006). Stock Take: Delivering improvements in existing housing. London, Sustainable Development Commission.

Tyndall Centre. (2005). "Decarbonising the UK: Energy for a climate conscious future." Retrieved 16/01/09, from http://www.tyndall.ac.uk/media/news/tyndall_decarbonising_the_uk.pdf.

UK Green Building Council (2008). Low Carbon Existing Homes. London, Green Building Council.

WWF (2008). How Low? London, WWF.

## Acknowledgements

Thanks are due to Rob Wall at De Montfort University, and Simon Graham, Mary Popham and Nic Wedlake at Peabody for feedback on this research. Thanks to Steven Firth for the use of data from the Community Domestic Energy Model.

This research has been carried out through an EPSRC-funded CASE studentship, delivered through the INREB Faraday partnership, with support from Peabody.