Towards a Low - Carbon Peabody

Exploring the viability of achieving deep carbon dioxide emission cuts from existing Peabody homes.

A report for Peabody's 21st Century Communities project

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PEABODY

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GLOSSARY OF ABBREVIATIONS

ASHP: Air Source Heat Pump
BD: Breaking Down scenario
CA: Conservation Area
CHP: Combined Heat and Power
CO_2: Carbon dioxide
COM: Communal package
FAB: Fabric package
FIT: Feed-in Tariff
FP: Fuel Poverty
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
REN: Renewables package
RHO: Renewable Heat Obligation
RO: Renewable Obligation
ROC: Renewable Obligation Certificate
SD: Sustainable Development scenario
SPC: Shadow Price of Carbon
TRV: Thermostatic Radiator Valve

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EXECUTIVE SUMMARY

Achieving deep cuts in carbon emissions from existing homes will be one of the major challenges facing social landlords over coming decades. The viability of meeting this goal for existing Peabody stock has been assessed for this report.

The findings indicate that there is great potential to meet this goal through physical improvements to existing Peabody estates. However, if challenging carbon reduction targets are to be met, action by Government to decarbonise the grid and action by residents to constrain energy demand is also a necessity.

Substantial stock refurbishment is likely to be required for Peabody estates, with solid-walled dwellings being insulated and estates being connected to low-carbon communal heating systems where viable. To achieve deeper emission cuts, micro-generation technologies such as solar photovoltaics are likely to be required.

Even with considerable financial support from Government, these improvements will require substantial extra expenditure. In fact, this research points to a future context for carbon reduction refurbishment at Peabody where improvements may not lead to overall savings over the long term. As a result, if rent increases were used to fund the considered emission reduction measures, they would outweigh fuel bill savings, leaving residents worse-off financially.

If the task of carrying out comprehensive carbon reduction refurbishment is taken up Peabody, or any social landlord, this research implies that this would be likely to lead to increased costs that the current funding model for social housing is unlikely to be geared up to deliver. This raises important questions on how this increased funding should be delivered.

Deep emission cuts can be achieved in social housing, but this research implies that strong action is required by all stakeholders involved, in particular Government, residents, and landlords such as Peabody. This report goes some way towards clarifying some of the challenges and issues involved, and points towards strategies for making strong action on climate change mitigation in the social housing sector a reality.

Context and Aims

Over the coming decades, the UK faces the considerable challenge of achieving deep cuts in carbon emissions from its existing housing stock, to play its part in 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 refurbish existing housing.

For housing associations such as Peabody, this process 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 these issues by identifying the stock refurbishment measures that will be required to achieve deep carbon emission cuts from Peabody's existing stock over the long term.

The research has measured future progress against two targets:

- carbon reduction goals set by the Greater London Authority (GLA) in its Climate Change Action Plan, which calls for 60% reductions from 1990 emission levels in London by 2025
- the goal of achieving zero net carbon emissions across Peabody stock by 2030.

Applying the GLA's target for 2025 to existing housing leads to a goal of achieving 57% reductions in emissions from 2006 emission levels by 2025. This goal is used to assess Peabody progress against the GLA target.

The impact of the national policy and regulatory environment on what can be achieved was also considered. The financial viability of action by Peabody was also assessed, alongside the potential extent of fuel poverty on Peabody estates under different refurbishment approaches over coming decades.

Methodology

The impacts and costs of refurbishment approaches have been modelled using the Peabody Energy Model. This is a stock-wide model developed for this research that quantifies energy use and energy costs for 189 existing Peabody estates on a year by year basis, from the base year 2006 to 2030.

Established approaches for modelling domestic energy demand are combined with assumptions about the performance of refurbishment measures (e.g. micro-generation) and assumptions about resident demand for energy to produce the model's outputs.

The research assumes that Peabody's current planned work to meet the Decent Homes standard continues to 2010. From 2011 to 2030, several approaches to refurbishment are modelled, ranging from a base case of continuing with the current planned refurbishment approach, to approaches maximising the use of micro-generation, community heating with combined heat and power (CHP) and building fabric improvements.

Only existing mature technologies are considered as refurbishment options, and all new installations are carried out by 2025. A number of constraints are initially applied to refurbishment measures: external insulation, solar PV and solar thermal are not installed on estates in conservation areas, and to avoid disruption, residents are not temporarily re-housed ("decanted") so internal insulation can be installed. The impacts of changing these, and other assumed constraints, are also explored.

Four future scenarios are employed to set the broad social context in which the refurbishment approaches take place (see below). The scenarios used were based upon two key factors impacting on outputs of the model: the extent to which UK society acts to mitigate climate change (strong or weak action) and the nature of fuel prices (low and stable, or high and unstable).

Keeping the Lights On (KLO) 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) 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) 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) High fuel prices, strong action on climate change.	Strong efforts to reduce carbon emissions with a focus on a reduction in 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.

Findings

Meeting the GLA's target

Of the four scenarios modelled, the GLA's target for 2025 can only be met with a good degree of confidence in the Sustainable Development and Power Down scenarios. This is due to the strong reliance on reductions in carbon intensity of grid electricity and reduced energy demand from residents. Peabody therefore cannot meet the GLA's target through its efforts alone.

The extent of stock refurbishment required depends significantly on these external factors. For the two scenarios above, comprehensive solid wall insulation, connections to district heating networks and some deployment of micro-generation are required.

The analysis of cost-effectiveness of refurbishment measures indicates a preference for solid-wall insulation, connection to district heating networks and installation of biomass boilers on estates over measures such as solar PV and gas-fired CHP. Micro-generation measures such as solar PV, solar thermal and heat pumps do however become more cost-effective in scenarios where Government offers them significant financial support.

The stock investment and spending required by Peabody to meet the 2025 target can be increased or decreased significantly by the extent of emission reductions that are brought about due to factors outside of its control, such as by more renewables feeding in to the national grid. If progress on emission reduction external to Peabody is slow, extensive use of measures such as solar PV and solar thermal would be required, adding significantly to the expenditure required.

Refurbishment on this scale may be needed in any case if Peabody is to go beyond meeting the GLA target to achieve reductions of the order of 80-90% using existing technologies.

Impacts of stock type

Peabody stock differs markedly in its makeup from other social housing stock (having much more pre-war homes) and other housing in London (having a greater proportion of flats).

The impact of this on the results was assessed by splitting Peabody stock into five broad 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.

For all stock types, base emissions in 2006 are below the UK average (see table below). This is largely due to Peabody homes being smaller and having fewer residents than average UK homes. Emissions on a per dwelling basis are relatively high for scattered properties, as these are generally larger than the rest of Peabody stock. On a per resident basis, emissions are highest in electrically-heated homes and in older homes (where the building fabric and heating systems are less efficient).

Stock Type	2006 emissions per home per annum / t	2006 emissions per resident per annum / t	Emission reductions to 2025 (PD scenario)	2025 emissions per resident per annum (tonnes)
Modern (14% of stock)	2.5	1.4	48%	0.7
Recent (14% of stock)	2.8	1.4	57%	0.6
Old (51% of stock)	3.7	2.2	74%	0.6
Electric (3% of stock)	4.0	2.4	70%	0.7
Scattered (18% of stock)	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

The emission reductions achieved for different stock types are illustrated for an approach that meets the 2025 target with a good degree of confidence in the PD scenario. 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. Peabody's post-war stock would require the installation of relatively costly micro-generation technologies, such as solar PV, to meet the 2025 target.

The relative difficulty in achieving emission reductions in more modern stock, which is more typical of the broader housing association sector, could imply that greater reductions need to be achieved in older, less-efficient homes to offset this. This could mean 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.

Achieving Zero-Carbon

An estate can be described as zero-carbon if the net on-site carbon emissions are zero or less. Net emissions are the total carbon emissions arising from on-site energy use subtracted by any emissions saved due to on-site electricity generation.

For Peabody stock to achieve zero-carbon status by 2030, radical change in the generation of grid electricity is necessary, so that it is produced entirely from zero-carbon sources by 2030. This is because there is insufficient space on Peabody estates to install sufficient solar PV to offset the estates' carbon emissions. Having a greater proportion of grid electricity coming from renewables does not lead to zero-carbon Peabody estates as this also leads to a reduction in the impact of solar PV in offsetting emissions, as the electricity it displaces becomes cleaner.

The technical viability of developing a zero-carbon grid is uncertain, although the Centre for Alternative Technology has outlined a broad approach for achieving this in the UK by 2027 (CAT 2007), and a close to zero-carbon grid by 2030 has been recently called for by the UK's Committee on Climate Change (Committee on Climate Change 2008).

The political viability of this goal is even more doubtful, as achieving this would require radical changes in the perceived level of action required to mitigate climate change from both the public and Government, and strong co-ordinated action by Government and industry, going far beyond any level of action planned at present.

If grid electricity is produced without carbon emissions, no carbon emitted on Peabody estates can be offset against the grid. As a result, for Peabody homes to achieve zero-carbon status, no natural gas can be used to provide energy on its estates, either for boilers or communal heating.

In this context, Peabody stock could technically achieve zero-carbon status by simply being powered entirely by electricity. However, in practice, substantial demand reduction is likely to be required to make a zero-carbon UK viable. To play its part in this demand reduction, it is likely that Peabody stock would need a comprehensive programme of solid wall insulation and installations of solar thermal and solar PV where viable. Electricity could be used for supplying heat more efficiently by the installation of both ground and air source heat pumps where appropriate. Any communal heating systems would need to be fuelled entirely by biofuels, such as wood or biogas.

Financial viability

For each scenario and approach to refurbishment considered, stock improvements that go beyond Peabody's planned approach to refurbishment require an increase in net expenditure. They are therefore not financially viable unless additional funding is sourced by Peabody.

This result is identified even where considerable financial support for from Government for refurbishment is assumed in the SD and PD scenarios. In the SD scenario, this includes:

- 20% of Peabody estates refurbished at no cost to Peabody through a 'Low Carbon Zones' programme[1]
- Estates not in 'Low Carbon Zones' receive grant funding towards insulation (covering 20% of all costs)
- Grants are available for micro-generation technologies (covering 30% of costs).
- Feed-in tariffs are introduced to support investment in solar PV systems.

The financial impacts of refurbishment are calculated by considering all cash flows up to 2030 that arise from each approach. The net present value (NPV) of each approach relative to Peabody's current spending plans is then calculated to establish if the investment is beneficial or not for Peabody[2].

For the lowest cost approaches that meet the 2025 target with a good degree of confidence, the NPV for Peabody is minus £77 million for the Sustainable Development scenario, and minus £54 million for Power Down. Although there is significant uncertainty attached to cost estimates for refurbishment approaches, the conclusion that the NPV is negative in each case appears to be robust. If no grant funding is assumed, these figures increase in magnitude to minus £105million for the SD scenario and minus £91 million for the PD scenario.

Each approach considered also has a negative NPV where Peabody and its residents are considered as a whole. This indicates that even where the reduction in fuel bills achieved by refurbishment is taken into account, Peabody and its residents are financially worse off overall when each approach is carried out.

This result also demonstrates that if rents were increased after refurbishment so that residents' savings could be used to subsidise Peabody's investment costs, this would not generate enough funds to make investment cost-neutral for Peabody. If refurbishment was paid for wholly by rent increases, residents would be worse off overall.

This situation contrasts sharply with the context of carbon reduction refurbishment over recent decades, where improvements such as loft insulation are expected to lead to fuel bill savings over the long term.

Impacts of stock type on expenditure

The type of estate considered has a significant impact on the results for NPV. The table below illustrates the NPV results for the Power Down scenario for two approaches: the lowest cost approach to meeting the 2025 target with a good degree of confidence (insulating solid-walled estates, decanting residents if necessary; installing biomass boilers; connecting to district heating networks), and a more extensive approach that also includes solar thermal and solar PV, taking predicted emission reductions to 2025 up to 74%. In both cases the figures given assume that no grant funding is available. The broad trends are representative of the patterns for the other scenarios.

The results indicate that for the most cost-effective approach, total expenditure is largely concentrated on Peabody's older estates. Considering the average NPV for each stock type, this approach requires little expenditure on post-war homes which are currently relatively energy efficient.

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[1] 'Low-carbon Zones' are a policy solution proposed by Brenda Boardman in "Home Truths: A low-carbon Strategy to Reduce Carbon Emissions by 80% by 2050".

[2] Net Present Value is a measure of the cost effectiveness of an investment strategy. Future cash flows are discounted and given less weight than cash flows in the present day.

Stock Type	No. units (projected from 2011)	Total NPV to 2030 for most cost-effective approach	Total NPV to 2030 for more extensive approach	Average NPV to 2030 for most cost-effective approach	Average NPV to 2030 for more extensive approach
Modern	2351	-£0.9m	-£12.6m	-£390	-£5,350
Recent	2304	-£3.7m	-£15.2m	-£1610	-£6,590
Old	8210	-£54.9m	-£69.3m	-£6680	-£8,440
Electric	456	-£3.7m	-£5.6m	-£8310	-£12,260
Scattered	2981	-£28.0m	-£46.8m	-£9390	-£15,690
TOTAL / AVERAGE	16302	-£91.2m	-£149.5m	-£6000	-£9170

Electrically heated estates have high refurbishment costs, due to the assumption that electric systems are replaced with gas to reduce resident fuel costs. Refurbishment costs could be reduced by removing this assumption, which would have little impact on the emission reductions achieved in the PD and SD scenarios.

Where the more extensive approach to refurbishment is considered, this increases costs significantly and has a proportionately greater impact on post-war Peabody homes, which are less likely to be in conservation areas, and therefore more likely to have solar PV and solar thermal installed.

Bridging the funding gap

If the extra funding required to pay for refurbishment in the successful scenarios can not be made available through a re-allocation of internal resources, the two principal methods available to Peabody to bridge the funding gap are increased rents or sales of homes on estates. Both methods are unlikely to be desirable for a social landlord such as Peabody, but the implications of these two approaches are reported here to illustrate the possible impacts of meeting the GLA target.

Depending on the extent of refurbishment required and grant availability, annual rent increases in the range of 0.2% to 0.9% per annum (leading to an overall increase of between 4% and 19% by 2030), or sales of between 210 and 730 homes would be needed to bridge the funding gap.

There may be some potential for the use of rent increases in Peabody's case, as its existing rents are lower than average social rents in London, and some way below Government-set target rents for its stock.

If permitted by Government, faster convergence towards target rents at Peabody could generate sufficient extra income to fund the more-extensive refurbishment options considered in this research. If this option remains unavailable to Peabody and without further grant funding, sales of stock would be likely to be required to bridge the funding gap.

Fuel Poverty

For Peabody residents, this research indicates a potential increase in the prevalence of fuel poverty, due to the assumption that fuel costs increase in real terms to 2030 for all scenarios.

If Peabody's planned approach to refurbishment is carried out, fuel poverty levels increase from the 2008 level of 3% in each scenario. For this approach, around 6% of Peabody residents are in fuel poverty in 2030 for all scenarios except Breaking Down, where the assumed high fuel costs lead to over 25% of Peabody households living in fuel poverty.

Applying solid wall insulation on Peabody estates (either externally, or internally in void dwellings for estates in conservation areas) is the most effective measure for combating fuel poverty.

If fuel prices remain close to present-day levels, Peabody can virtually eliminate fuel poverty on its estates through insulating all its homes. If fuel prices rise significantly, as is assumed in the Breaking Down scenario, then it will be difficult to prevent a fraction of Peabody residents from living in fuel poverty.

Recommendations for Peabody

A number of recommendations for Peabody arise out of this research, both in terms of practical action and organisational change.

Over the short term Peabody should look to gain further experience of the refurbishment measures that have been identified as important for the achievement of deep emission cuts. This would add to Peabody's knowledge base on the practical and economic factors affecting each measure, give improved knowledge of the emission reductions that can be achieved, and help to identify the views of Peabody residents on the considered measures.

This can be done most efficiently by identifying estates which are already due for refurbishment or maintenance work, and incorporating further carbon reduction measures alongside it.

Solid wall insulation is the most important measure identified by this research, so it is recommended that Peabody looks to identify estates that can receive this measure alongside planned Decent Homes work over the next few years.

Carrying out this work would present an important research opportunity, and it would be greatly beneficial to Peabody and the wider housing sector to monitor energy use in the treated homes before and after refurbishment to identify the impact of the insulation improvements.

Peabody should also look to gain experience of converting an estate currently fuelled by individual heating systems to a communal system. The most likely opportunity would be through estates with potential to connect to a nearby district heating system.

If estates can be identified with sufficient space to make an on-site communal biomass system technically feasible, this option is also worth pursuing. Research by Dwyer (2007) indicates that this may be the case for Peabody's Camberwell Green estate.

Peabody does not yet have experience of solar thermal technology, so opportunities to install this technology should also be sought. An ideal opportunity would be if both re-roofing works and central heating replacement are planned through the Decent Homes programme for any existing Peabody estates.

Over the longer term, Peabody should consider a comprehensive programme of solid wall insulation for their stock, ideally basing their decision on whether to proceed on the results of refurbishments carried out over coming years.

The deployment of many of the other considered technologies should depend on contextual factors such as the availability of low-carbon energy sources. For example, Peabody should wait until good progress on grid decarbonisation is achieved before considering switching homes to electric heating.

Organisationally, if funding is to be made available for the measures described above it is likely to require an organisational commitment from Peabody to achieve deep reductions in emissions from its stock.

A commitment could take a more tangible form through an emission reduction target, a SAP target (minimum and/or average), or as a commitment for all Peabody homes to have adequate insulation. A target of this nature may be forced upon social landlords through regulation in any case if Government carries out some of the policy recommendations that have been put forward for achieving emission cuts in existing housing.

Peabody should also look to actively develop capacity to successfully manage carbon reduction technologies such as CHP or solar PV which require new ways of working. An Energy Service Company (ESCo) approach may be useful in this context, so that the management of low-carbon technologies across Peabody stock can be handled by specialised staff.

Broader implications of research

Change external to Peabody has been shown to be vital if deep carbon emission cuts are to be achieved. This conclusion is likely to be as true for Peabody as it is for other social landlords.

Significant decarbonisation of the grid is a key issue and the ambitious targets put forward by the Committee on Climate Change (2008) for substantial grid decarbonisation offer a useful goal for Government to work towards.

A viable funding strategy for Peabody could involve the ability to increase rents, but this is not possible in the current regulatory context. Much prior work on carbon reduction in social housing has identified this barrier, and this research supports the idea that Government should allow some flexibility for landlords to raise rents to offset refurbishment costs.

The need to minimise residents' demand for energy is another crucial issue. Whilst this is dependent to a large degree on broad social causes, a wide range of policies are available to Government to help reduce domestic energy demand, and these should be actively pursued.

For social landlords, the research findings imply that if the task of carrying out comprehensive carbon reduction refurbishment is to be taken up, 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), through the sale of social housing stock, or through reducing spending on other services and operations. Each of these approaches is problematic, but some combination of them is likely to be necessary to fund deep emission cuts in social housing.

The research findings presented here should also be understood in terms of the broader discussion around the most desirable strategies for mitigating climate change 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 raise the question of whether further reductions are better achieved 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 on social housing refurbishment 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.

1. INTRODUCTION

1.1. Context

Energy is used in homes to provide useful services for householders, such as heat, hot water and power for appliances. As a result of the use of fossil fuels to provide this energy either directly (such as gas for central heating) or indirectly (such as coal for coal-fired power stations), this energy use results in carbon dioxide (CO_2) emissions. The need to reduce these CO_2 emissions that result from energy use in housing is a key part of the UK's efforts to combat climate change.

Challenging targets for emission reductions have been set both by national and regional government in the UK. The UK Government has recently committed to a minimum of 80% reductions in UK CO_2 emissions by 2050 (DECC 2008). In London, the Greater London Authority (GLA) has called for a 60% reduction in carbon emissions[1] by 2025 in its Climate Change Action Plan (GLA 2007). In both cases, it has been suggested that housing should play an equal role in achieving these reductions as other sectors.

Peabody (until recently known as the Peabody Trust) is one of London's largest housing associations, managing around 18,000 homes in the greater London area. The Peabody stock dates from the 19th century to the present day, with the majority being purpose-built blocks of flats.

More than half of its stock consists of pre-war solid-walled flats and houses, making energy efficient refurbishment technically challenging. Furthermore, around 44% of homes on Peabody estates are in conservation areas, creating a potential conflict between carbon emission reduction and the desire to maintain the appearance of architecturally-significant buildings.

Peabody is currently undertaking research to identify what "an exemplar 21st century Peabody community would look like" to inform its strategic planning over the next 25 years (Peabody Trust 2007). Five case study estates are being considered for the research: Fort Street, Pembury, Wild Street, Rosendale and Peabody Hill (table 1.1 and figure 1.1.1), although the research aims to draw conclusions for Peabody stock as a whole.

This report aims to address one aspect of the aims of the 21st century Peabody Community project, by identifying the future implications for Peabody stock of the need to achieve deep cuts in carbon emissions. The viability of achieving these emission cuts within Peabody homes is assessed for different refurbishment approaches, and the impacts on residents' fuel costs and Peabody expenditure are explored. The report focuses on the whole Peabody stock and the implications for Peabody as a whole. The main implications for the five 21st Century Community estates are also reported.

This work is based upon ongoing PhD research at De Montfort University, undertaken through an EPSRC-funded CASE studentship, as part of the INREB Faraday partnership programme of research.

Estate	Year Built	No. Units	Description
Fort Street	1996	224	Fort Street contains terraced houses, a five-storey block known as Royal Victoria Place and a number of low rise blocks of flats scattered throughout the West Silvertown Urban Village
Pembury	1935 – 1970	1225	The Pembury estate has two distinct parts: Old Pembury and New Pembury. Old Pembury comprises 24 walk-up blocks (919 dwellings) dating from the 1930s. New Pembury consists of streets of maisonettes and bungalows dating from the 1960s.
Wild Street	1882	219	A high density Victorian estate, comprising terraces of 6-storey staircase access flats, located in a conservation area.
Rosendale	1905	304	Rosendale comprises a mixture of 2-storey cottages and 4-storey flats, located in a conservation area
Peabody Hill	1975	253	Peabody Hill is adjacent to Rosendale, and consists of terraces of houses and flats, none more than three storeys high.

Table 1.1 The 21st Century Community Estates

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1. the terms "carbon emissions" and "CO_2 emissions" are used interchangeably throughout this report. Any references to quantities of emissions refer to carbon dioxide (CO_2), not carbon.

Pembury

Rosendale

Peabody Hill

Wild Street

Fort Street

Figure 1.1.1 21st Century Community Estates

1.2. Aims

The aims of the work undertaken for this report are to:

1. Identify the viability of achieving deep cuts in CO_2 emissions from existing Peabody homes

> *where progress is measured against two distinct targets: the target set for London in the GLA's Climate Change Action Plan, of 60% reductions relative to 1990 levels by 2025, and the aspiration of achieving zero net carbon emissions by 2030.*

2. Identify the conditions under which the CO_2 emission reduction targets are met

> *with conditions including those external to Peabody (such as the availability of grant funding or behaviour change by Peabody residents) and those internal to Peabody (such as decisions on stock refurbishment).*

3. Identify the financial implications of measures taken by Peabody — both for Peabody and its residents

> *with consideration being given to residents' annual fuel costs, levels of fuel poverty, investment costs for Peabody and the cost-effectiveness of investment strategies.*

1.3. Previous Research

Since 2003, Peabody has commissioned a number of pieces of research to identify the stock improvement measures required over the coming 20–25 years in order to minimise resident fuel costs and CO_2 emissions, whilst keeping stock investments as cost-effective as possible.

In 2003 the consultancy Rickaby Thompson Associates (RTA) addressed these aims for Peabody through its Strategic Heating Review (Rickaby Thompson Associates 2003). The report's principal recommendation was that Peabody should shift from the current practice of providing individual gas central heating to existing flats on dense, inner-city estates, and instead look to install communal heating, supplied by gas-fired combined heat and power (CHP). It was argued that this measure would reduce resident fuel costs, Peabody maintenance costs and carbon emissions.

A parallel PhD research project at the University of Ulster (also an INREB Faraday partnership CASE studentship) is considering these aims for one Peabody estate, Camberwell Green (Dwyer 2007). This is a solid-walled estate consisting of several 6-storey blocks of flats, which was chosen as a representative example of Peabody stock. The implications of different approaches to refurbishment for the estate are being considered under different fuel cost scenarios. Each approach was assessed using three model outputs: annual fuel costs to residents in 2030; percentage reduction in carbon emissions from 2005 to 2030; Net Present Value (NPV) of refurbishment strategies.

This report aims to extend the research performed to date by RTA and Dwyer. The method of assessment employed by Dwyer, using the three model outputs described above, was applied to the whole Peabody stock. This approach was extended by evaluating the NPV of refurbishment approaches both for Peabody alone and for Peabody and its residents considered as a whole. The extent of fuel poverty on Peabody estates under different refurbishment approaches was also estimated.

The measures recommended by RTA and Dwyer are considered, with the extension of modelling further micro-generation options (solar photovoltaics, ground source heat pumps and air source heat pumps), advanced insulation improvements, connections to district heating schemes and the potential use of biomass-fired combined heat and power.

1.4. Report Structure

The methodology used for the research is described in chapter two, with a more detailed description of the methods used being given in the Appendices document that accompanies this report, in Appendix I.

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Chapters three to five explore the research findings in detail. Chapter three describes the impacts of the four original approaches to refurbishment considered, with results assessed under four future scenarios. Chapter four reports the results of sensitivity analysis on the assumptions used in the research, with further detail on this being given in Appendix IV. In chapter five the results are analysed to identify the cost-effectiveness of refurbishment measures and the impacts of changing the approaches or constraints assumed in the model.

Chapter six then uses the findings of the previous three chapters to describe approaches for meeting the GLA’s carbon reduction target for each scenario, and to explore the viability of achieving zero net carbon emissions from Peabody homes by 2030.

Chapter seven summarises the report’s main conclusions and provides recommendations for Peabody and policymakers based upon the research findings.

2. METHODOLOGY

2.1. General Approach

To meet the research aims given above, the Peabody Energy Model — a model of energy use, energy costs and intervention costs for Peabody stock — has been developed.

The model considers energy use in the Peabody stock on an estate by estate and year by year basis, from 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 continues to 2010. From 2011, distinct approaches to refurbishment are modelled, ranging from a base approach of current planned levels of refurbishment, through to approaches making significant use of micro-generation, communal heating and solid wall insulation. The modelling approach is described in detail in Appendix I.

Average annual carbon dioxide emissions per dwelling are calculated for each estate from 2006 to 2030. These figures are used to evaluate progress towards meeting the GLA's 2025 carbon reduction target. Average annual fuel costs for Peabody residents are calculated for each estate from 2006 to 2030, and are used to estimate the prevalence of fuel poverty. Total expenditure and income arising from each refurbishment approach is calculated for each year from 2011 to 2030.

To assess the financial case for refurbishment, the net present value (NPV) of each approach relative to the base approach is calculated for the period 2011 to 2030. Although the NPV approach 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.

NPV is evaluated in two ways: for both Peabody and its residents considered as a whole (to identify the "social case" for refurbishment, irrespective of split incentives between landlord and tenant); for Peabody considered alone (to identify the "business case" for Peabody). NPV is calculated by summing cash inflows and outflows over the assessment period, with a discount rate applied to these figures to take into account the reduced weight attached to spending and income the later they occur.

Uncertainty about the impact of future socio-economic conditions on model results is addressed by specifying four scenarios under which the refurbishment strategies considered could take place.

2.2. Refurbishment strategies

Four approaches to refurbishment up to 2030 have been considered, based upon the recommendations made for Peabody by Rickaby Thompson Associates (2003) and Dwyer (2007) (table 2.1). A full description of each approach is given in Appendix I.

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. No changes are made to building services, except for existing individual and communal gas boilers being replaced by new models when due for replacement.
Fabric	Improvements to building fabric and some building services are carried out after 2010 on each estate. 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 schemes where a connection is available, and communal heating supplied by combined heat and power (CHP) is installed on other estates where feasible.
Renewables	As for the Communal approach, but photovoltaic (PV) panels and solar thermal panels are installed on available roof space.

Table 2.1 Refurbishment strategies.

2.3. Scenarios

A number of broad societal issues, such as Government policy, economic conditions and social values, will have a significant influence on the carbon emission cuts that can be achieved in Peabody stock. As future conditions are uncertain, scenarios have been used to specify a range of possible futures in which the considered approaches to refurbishment are carried out.

In existing research on future trends in energy use in housing and UK carbon emissions, a number of key issues affecting domestic emissions have been identified. 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 (IPCC 2000; ACE 2005; Boardman et al. 2005; BRE 2005; Johnston et al. 2005; Tyndall Centre 2005).

In addition, scenarios-based research focussing on broader social trends over coming decades has identified a number of key issues around which future decades could be defined: levels of social cohesion, openness of economies; dominant values (social or individualistic); scale of economies (globalisation or localisation) (Carnegie Trust 2007; Skea and Nishioka 2008; Young Foundation 2008).

Scenarios are best defined around issues that are both highly significant for research outcomes, relatively independent of each other, and for which there is a high degree of uncertainty attached (Schwartz 1991). Using this principle, two issues have been chosen to define scenarios that capture many of the issues listed above, and which are intended to provide a frame in which future socio-economic trends affecting research outcomes can be understood. These are trends in fuel price levels and the extent of action taken in the UK to mitigate climate change.

2.3.1. Fuel price levels

The future prices for domestic fuels used on Peabody estates (gas, electricity and potentially biomass) will determine fuel bills for Peabody residents, and as a result, the extent of fuel poverty. In addition, they affect the financial case for investments: for example, high electricity prices relative to gas prices improves the financial case for CHP.

Fuel price levels can also be expected to be associated with a number of the scenario issues discussed above. Very high fuel prices are likely to lead to reduced demand for energy. Politically, they are likely to lead to a greater focus on providing affordable warmth in housing, creating more support for insulation measures.

Domestic fuel price levels have been historically correlated with the price of oil, and this trend is likely to continue for the foreseeable future (Powry Energy 2007). Oil prices have fluctuated significantly over recent years, rising sharply until mid-2008, and then declining significantly as the recent global economic downturn led to a reduction in demand. However, the context over coming years is likely to be one of supply struggling to match demand, leading to the conclusion expressed by both Government and energy industry officials that “the era of cheap oil is over” (Golby 2008; Hutton 2008; IEA 2008).

It is therefore assumed that for every scenario the overall trend in fuel prices to 2030 is upwards in real terms. However, there is disagreement and considerable uncertainty on the nature of fuel price changes over coming decades and the knock-on impacts on the global economy.

Some analysts have pointed to the current dependence of the global economy on energy from oil (Greene et al. 2006), and a likelihood of declining supplies over coming decades (Campbell and Laherrere 1998; Hallock et al. 2004) leading to a potential contraction of the global economy (Hirsch et al. 2005; FEASTA 2007).

Contrasting with this perspective is the view taken by the UK Government, that “global oil (and gas) reserves are sufficient to sustain economic growth for the foreseeable future” (Monbiot 2008), where “the foreseeable future” refers to the period cited in research by the International Energy Agency (IEA 2005), namely from the present day to 2030.

Scenarios are therefore defined around these two contrasting futures, with relatively low fuel price increases and continued economic growth informing one pair of scenarios, and high fuel prices and stalled economic growth defining the second pair of scenarios.

2.3.2. Climate change mitigation

The level of action taken in the UK, both by Government and wider society, to mitigate climate change (by reducing carbon dioxide emissions) affects a number of key issues impacting on energy use in Peabody homes.

Substantial investment in renewable energy for the national grid, or decentralised generation within London, would provide sources of low-carbon energy for Peabody homes. Measures to bring about changes in energy use behaviour, such as bringing in a system of Tradable Energy Quotas (Fleming 2007), or improved feedback for householders on energy use (Darby 2006), could significantly reduce demand for energy in Peabody homes, and in the UK as a whole.

There is some uncertainty about the approach that will be taken in the UK to reduce carbon emissions. The UK Government has recently committed to a statutory carbon reduction goal of 80% reductions by 2050 (DECC 2008), which will potentially trigger strong action.

However, UK energy policy is also defined in terms of energy security, and potentially carbon-intensive energy sources such as new coal-fired power stations are currently being actively considered by Government.

There is therefore some uncertainty around the extent to which climate change mitigation will be pursued in the UK over coming decades. This feature was therefore also used to distinguish scenarios, with two scenarios defined around strong efforts to mitigate climate change, and two scenarios defined around relatively weak action.

2.3.3. Four scenarios

Four scenarios were chosen based upon the two defining features described above (table 2.2). The defining qualities of each scenario and the “back-story” in terms of broader societal changes are illustrated in figure 2.3.1. Each scenario is intended to provide a broad story of a possible future under which the considered refurbishments are carried out.

The position of each scenario in figure 2.3.1 is intended to represent visually where it fits into the range of future possibilities as defined by the two axes. The scenarios are positioned close to the centre of the graph, as they are intended to represent relatively moderate changes, rather than more extreme visions of the future. For example, the strong response to climate change put forward in the report Zero Carbon Britain (CAT 2007) would be more radical in many respects than the action assumed for the Power Down scenario.

For each of the scenarios modelled, the broad scenario stories shown in table 2.2 and figure 2.3.1 were translated into assumptions affecting model outputs. These are given in full in Appendix III, and the key implications are shown in table 2.3.

Keeping the Lights On (KLO) 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) 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) 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) 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 2.2 The four scenarios

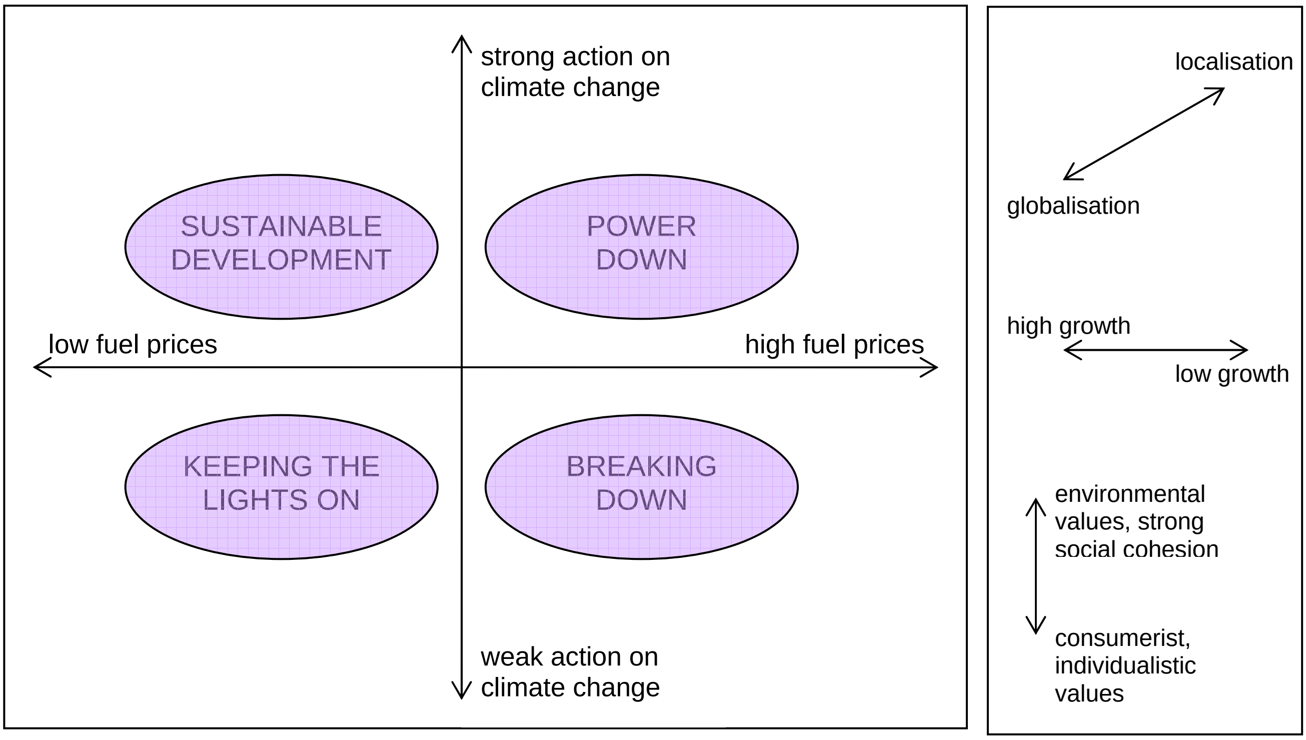

Figure 2.3.1 The four future scenarios and their defining features

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. Changes to 2030 for electricity: +48% (KLO); -7% (SD); -20% (PD); +2% (BD). 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” 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% 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.
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) and 113% (BD). Electricity prices are greater by 24% (KLO), 72% (SD), 113% (PD) and 92% (BD).

Table 2.3 Scenario assumptions

2.4. CO_2 reduction targets

Despite the increasing focus from policymakers on carbon reduction targets expressed in terms of reductions in quantified emissions, such targets have not yet been applied to social landlords, nor are they planned in the near future.

Government regulation is more likely to be defined around systems for appraising the energy efficiency of dwellings, such as the Standard Assessment Procedure (SAP), or by requirements to carry out specific carbon reduction measures (such as those recommended through energy performance certificates). Strategies that make use of such instruments have been proposed by researchers (Boardman 2007; Energy Saving Trust 2008), but a long-term Government strategy for the refurbishment of existing housing has yet to be put forward.

This research takes the position that regardless of the form of Government policies that may drive carbon emission reduction in Peabody stock, it is important to assess the reductions that can be achieved against carbon reduction targets. This section describes the targets used for this research, the rationale for this choice, and how the targets were applied to Peabody.

2.4.1. Choice of Targets

Progress on CO_2 emission reduction has been measured against the target in the London Climate Change Action Plan (reduction of London's emissions from 1990 levels of 60% by 2025, excluding emissions from aviation (GLA 2007)) and the longer term aspiration of zero net CO_2 emissions by 2030. The GLA target is broadly in line with the proposed target of an 80% reduction in UK emissions by 2050 recently adopted by the UK Government (DECC 2008).

The stated aim of the GLA target is to meet the goal set by the European Union and endorsed by the UK government of preventing a 2° rise in average global temperatures above pre-industrial levels (GLA 2007). It should therefore be noted that evidence from climate modelling indicates that their design is not consistent with a high likelihood of achieving that goal.

The GLA target is derived from work by the Tyndall centre on a carbon budget for the UK (ibid). This research assumed a stabilisation goal of atmospheric carbon dioxide of 450 parts per million by 2050. The Tyndall report itself claims that evidence from climate system models indicates that achieving this stabilisation goal provides only a 30–40% chance of preventing a 2° rise (Bows et al. 2006).

More recent research has provided evidence that the Earth's long-term sensitivity to greenhouse gas emissions could be twice the level assumed previously (Hansen et al. 2007). An increased climate sensitivity would imply that greater emission reductions are required to give the same likelihood of avoiding a 2° rise than those assumed in previous research, where a lower sensitivity was assumed.

The long-standing status of 2° as the threshold that should not be passed to avoid dangerous climate change has also recently been questioned, with lower thresholds of 1.7° (ibid) and even 0.5° (Spratt and Sutton 2007) being proposed. This perspective has been supported by research which indicates that the irreversible decline of the Greenland ice sheet, which would eventually bring about global sea level rises of up to 7 metres, would be triggered by an average global temperature increase in the range 1–2° (Lenton et al. 2008).

Given this context, if a low risk of severe climate change impacts is the desired goal of actions to reduce emissions, emission reductions required by 2025 are likely to be greater than those called for by the GLA's target. These considerations may lead to more demanding targets being set at a local, national or international level.

In the light of these issues, emission reductions at Peabody have also been assessed against a more challenging target, with the aspiration of achieving zero net carbon dioxide emissions from Peabody stock by 2030 being the target chosen. This approach is in agreement with the level of emissions called for by the Centre for Alternative Technology (CAT) in their report Zero Carbon Britain (CAT 2007), which based its goal of zero emissions in the UK on many of the issues discussed above.

The two targets used have been chosen so as to represent upper and lower bounds of the likely range of targets that may be called for over coming years to mitigate climate change.

2.4.2. Applying targets to Peabody

The London Climate Change Action Plan calls for 60% reductions from London's emissions by 2025, relative to a 1990 baseline. Using the target emissions for London's housing for 2025 given in the CCAP, target reductions for London's existing housing were calculated, relative to a 2006 baseline (see Appendix II).

This leads to a target reduction of 57.4% by 2025.

It is assumed that the level of reductions demanded for existing London housing by the GLA target also applies to the existing Peabody stock. It should be noted, however, that this approach can be questioned on a number of grounds.

One difficulty is that a significant proportion of Peabody's stock is either listed or in conservation areas (44% in conservation areas, relative to 18% in London as a whole). Concerns about preserving architectural heritage may limit the potential for carbon reduction refurbishment in such areas, implying that a less demanding target might be appropriate. This issue is explored in this research by considering the impact of preserving the external appearance of protected buildings on the emission reductions achieved.

A second difficulty with targets based on percentage reductions is that it could be argued on the grounds of equity that for homes and individuals currently emitting less carbon dioxide than the average, there is less of an obligation to make deep emissions cuts. This is likely to be the case for Peabody residents, as they live in smaller than average homes and earn lower than average incomes, factors correlated with lower domestic energy use. From this perspective, greater emission cuts should be made by current high-emitters, so that per capita emissions levels converge towards an acceptable low level.

Related to this issue is whether targets for Peabody's stock should be expressed through percentage emissions reductions, or as absolute targets for emissions per resident or per dwelling. The percentage reduction approach does not take into account the different potential to reduce emissions for different dwelling types. Where initial emissions levels are already low, substantial percentage reductions in emissions are likely to be harder to achieve.

There is also a difficulty related to fuel poverty, which is increasingly prevalent in social housing (Energy Efficiency Partnership for Homes 2007). If residents on Peabody estates are currently under-heating their homes due to financial constraints, it would be beneficial for those residents to take advantage of insulation improvements through increased room temperatures. As this reduces the emission reductions arising from refurbishment, a less demanding emission reduction target for Peabody could again be argued for.

These issues each provide motivations for less-demanding targets to be placed upon Peabody. However, good arguments also exist for more-demanding targets to be applied. These include: greater emission reductions being potentially required from the housing sector to compensate for lower levels of emissions reductions being achievable from other sectors such as transportation (Bows et al. 2006); social housing taking a lead in reducing UK emissions from housing (Boardman 2007); greater potential for emission cuts in currently inefficient homes.

This report does not take a position on these issues, but offers assessment of progress for Peabody against the GLA target as a useful, intuitive and well-defined measure of progress on carbon emission reduction.

2.5. Model Limitations

To simplify the Peabody Energy Model, the effects of a number of potentially relevant issues have not been explicitly calculated.

Current Peabody experience shows that Decent Homes improvements are refused in a minority of cases, typically by elderly residents wishing to avoid disruption. This means that the improvement works will be delayed until the end of the tenancy, and will likely incur a higher cost due to the loss of economies of scale. The model assumes no refusals, either for Decent Homes or other measures, and will therefore potentially over-estimate emission reductions to a small degree. Measures of cost relative to Peabody's planned refurbishment will be largely unaffected, as delayed Decent Homes improvements will need to be carried out for each approach considered.

Energy is used in communal areas of Peabody estates, mostly for lighting, adding to the total emissions per dwelling. This energy use has not been considered due to lack of available data, and as a result, the base emissions for estates with communal areas will be slightly under-estimated. The impact on results for emission reduction in the model should be minor, as energy use in communal areas represents a small fraction of total estate energy use. Furthermore, installations of energy efficient lighting in communal areas should enable emissions cuts to be achieved of a similar order to that modelled for each scenario.

This research does not consider changes to Peabody's stock that may need to be taken to adapt to climate change over the period to 2030, such as installation of shading for dwellings at risk of over-heating (ARUP 2008). Future climate change may also result in reduced heat demand, and increased demand for electricity for cooling. However the extent to which this may take place is unclear, and there is evidence from climate researchers pointing towards little warming taking place over the next decade (Keenlyside et al. 2008). Given the uncertainty, and the relatively small time horizon of this research (2030, as opposed to the 2050 horizon commonly used in other research in this field), changes in energy demand due to climate change are not considered.

The embodied carbon emissions for each modelled refurbishment approach have also not been considered. These are the emissions produced in the sourcing of raw materials, manufacture, installation and disposal of each refurbishment technology and fuel source. This omission is due to the focus on emissions "in use" for the assessment against carbon reduction targets, and due to a lack of comprehensive data on the embodied carbon emissions for each refurbishment option considered. It is however recognised that this is an important consideration when considering the overall effectiveness of approaches to reduce emissions.

Finally, only carbon reduction interventions that change the physical characteristics of Peabody stock or energy supply systems have been considered. It should be stressed that other interventions are also available to Peabody as part of a carbon emission reduction strategy, such as providing guidance to residents on use of heating system controls, providing residents with feedback devices that monitor electricity use, or providing residents with face-to-face energy efficiency advice.

Interventions such as these could play a valuable and potentially cost-effective role in reducing demand for energy in Peabody homes, especially when used in combination with physical measures. The impacts of behaviour change by residents are considered in this research through different levels of energy demand in the four scenarios studied.

3. INITIAL RESULTS

The initial results from the Peabody Energy Model for the four different approaches are reported in this chapter. The findings are reported in turn for the three main issues considered: carbon emissions, resident fuel costs, and the financial case for refurbishment.

3.1. Carbon Emissions

Emissions results for the baseline year 2006 are reported first and compared to UK average levels. Emission reductions from 2006 to 2030 are then reported for each scenario, with a discussion on whether the GLA target for 2025 is achieved. The viability of achieving zero carbon emissions is discussed in chapter six.

3.1.1. Baseline emissions

Average emissions per dwelling for Peabody stock and the 21st Century Community estates for the baseline year 2006 are shown in figure 3.1.1. The value for current UK average annual emissions per dwelling of 6.1 tonnes (Defra 2007b) is displayed for comparison.

The results indicate that emissions per dwelling on each estate and for the whole stock are below the UK average, with Peabody stock having average annual emissions of 3.6 tonnes per dwelling. This is largely due to Peabody homes being smaller than average (having an estimated average floor area of 57m^2) and having lower than average residents per home (2.0, compared to 2.3 in the UK (Defra 2007b)). This result is in agreement with research that identifies lower emissions in social housing relative to other tenures (Brandon and Lewis 1999; BRE 2006). Relative to the UK average, emissions on the considered estates range from 22% lower in the case of Rosendale to 55% lower for Fort Street.

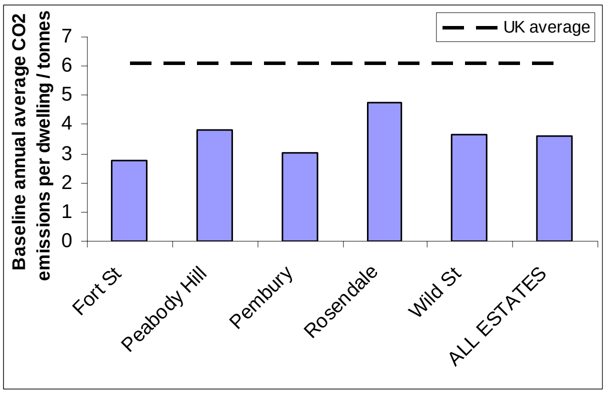

Figure 3.1.1 Baseline CO_2 emissions per dwelling

Emissions per dwelling for distinct types of estate are shown in figure 3.1.2. Estates are grouped into five categories, with electrically heated estates and estates of scattered homes considered separately, and remaining estates grouped according to their date of construction.

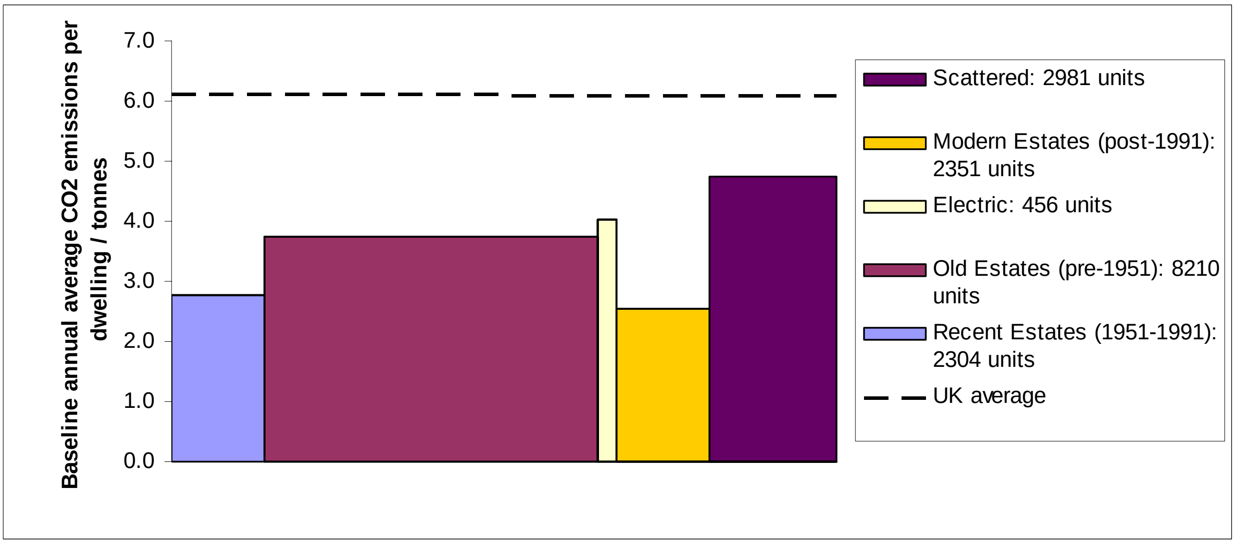

Figure 3.1.2 Baseline CO2 emissions per dwelling by dwelling type

The results indicate that the more recently constructed dwellings have the lowest overall emissions. Emissions on electrically-heated estates are relatively high, despite these estates typically being of modern construction, due to the higher carbon emissions currently associated with using electricity for heating. Dwellings on scattered estates have the highest impact, due to their relatively large floor areas and numbers of residents. The greatest total contribution to Peabody's emissions comes from its older stock, typically being solid-walled blocks of flats.

Figure 3.1.4 displays the baseline emissions per resident for each estate modelled, grouped according to estate type. The results indicate a clear trend of average emissions per resident declining the more recently an estate was built. The exception to this trend is estates with electric heating, which have higher emissions than those of a comparable age. Emissions are again typically below the UK average, although the average is exceeded on a small number of estates, most of which have electric heating.

The influence of stock age on emissions per resident is also apparent for the 21st Century Community estates (figure 3.1.3). Emissions per resident increase with age of the estate, with emissions on the two oldest estates approximately double those of the most recently built estate, Fort Street. The stock average for Peabody of 1.8 tonnes per annum is closer to the figure for the older estates, reflecting the greater proportion of older blocks of flats in Peabody stock. Relative to the national average, emissions per resident on these estates range from 19% lower in the case of Wild Street, to 61% lower in the case of Fort Street.

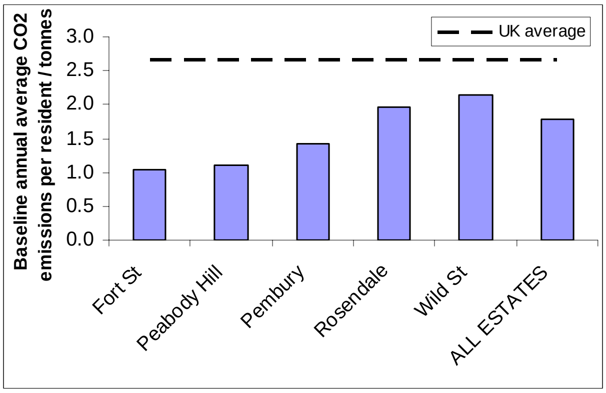

Figure 3.1.3 Baseline CO_2 emissions per resident for 21st Century Community estates

Based upon data from Defra on per capita domestic emissions in UK regions (Defra 2007c), domestic emissions per resident in London are approximately 8% lower than the UK average. Emissions per resident on the considered Peabody estates, being at least 19% lower than the UK average, are therefore also lower than the London average.

These results are in agreement with the points made in section 2.4.2, that emissions from Peabody estates are currently lower than the UK average, both in terms of emissions per dwelling and emissions per resident. It should be noted however, that these findings are based only upon model assumptions, and data of actual energy use on Peabody estates would be required to confirm their accuracy.

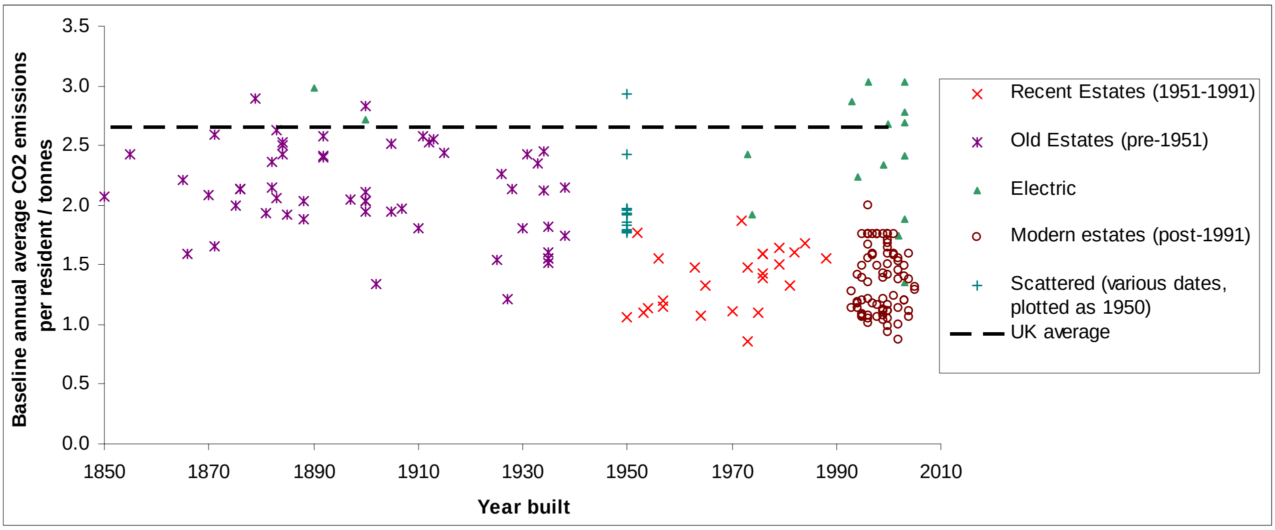

Figure 3.1.4 Baseline CO2 emissions per resident by estate

3.1.2. Emission Reductions

The emission reductions achieved to 2025 by each refurbishment approach under the four considered scenarios are shown below (table 3.1, figure 3.1.5).

The key result is that the 2025 target is only 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 is insufficient to meet the GLA's carbon reduction target.

	KLO	SD	PD	BD
Base	-19%	-41%	-46%	-30%
Fabric	-33%	-52%	-56%	-43%
Communal	-35%	-56%	-60%	-44%
Renewables	-42%	-63%	-67%	-51%

Table 3.1 Emission reductions to 2025

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.

Significant reductions are achieved in every scenario by the Base refurbishment approach (from 19% to 46%). This is due largely to the assumed increase in low and zero carbon electricity supplied to the national grid, alongside the gradual replacement of existing boilers with more efficient models. Reductions are greater in the PD and BD scenarios than the SD and KLO scenarios respectively, due to the assumed reduced demand for energy brought about by higher fuel prices.

Fabric measures have a greater impact where demand for heat is assumed to be higher, leading to the greatest extent of emission reduction in the KLO scenario, and the least in the PD scenario.

Communal heating has a relatively low overall impact. Emissions are lower in the SD and PD scenarios, due to an assumed greater availability of district heating connections for Peabody estates.

Further emission reductions are achieved to 2030 in each scenario due to assumptions of continuing declines in carbon intensity of grid electricity and demand for energy, and further installations of internal insulation in void dwellings as they become available (table 3.2). However the goal of achieving zero carbon emissions by 2030 is not close to being met.

	KLO	SD	PD	BD
Base	-21%	-46%	-53%	-37%
Fabric	-36%	-57%	-63%	-49%
Communal	-37%	-60%	-66%	-51%
Renewables	-44%	-66%	-71%	-58%

Table 3.2 Emission reductions to 2030

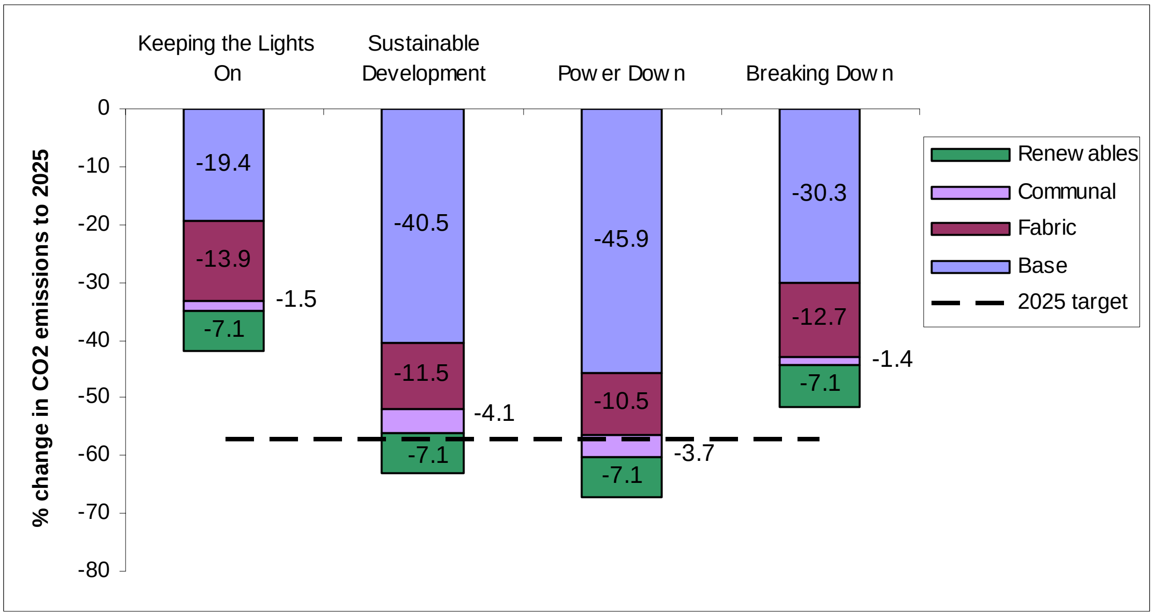

Figure 3.1.5 Emission reductions to 2025 by scenario

Reductions by stock type

Emission reductions achieved vary according to the type of stock treated. The results are shown (right) for the SD scenario, which has the same broad trends as for other scenarios.

For average emissions in 2025 (figure 3.1.6), the patterns described for 2006 emissions apply for the Base approach, with greater emission levels on older estates. Emissions on Electric estates have declined significantly, due to the reduced carbon intensity of grid electricity (an effect which is less marked in the KLO and BD scenarios). Fabric improvements have a significant impact on Old and Scattered estates, bringing emission levels down to a similar level to other estate types, although conservation area constraints hold back further progress. Communal installations bring further reductions on all estate types except scattered estates. Renewables have a relatively low impact on Old estates, which are frequently in conservation areas.

With regard to the GLA target, the greatest progress is made on Electric estates, although this is largely due to their poor initial performance. The target can be achieved on Old estates through fabric measures and communal installations. This approach has little impact on post-war estates where renewables are essential.

For the 21st Century Community estates, a general decline in emissions can be observed for each, punctuated by sharp drops in emissions where interventions are carried out (figure 3.1.8).

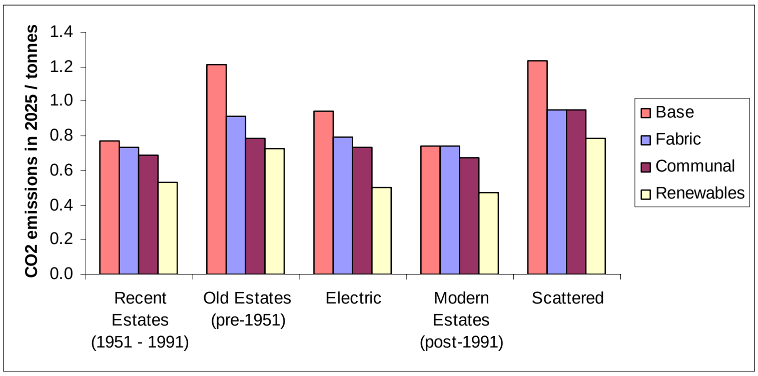

Figure 3.1.6 SD scenario: CO2 emissions per resident in 2025 by stock type

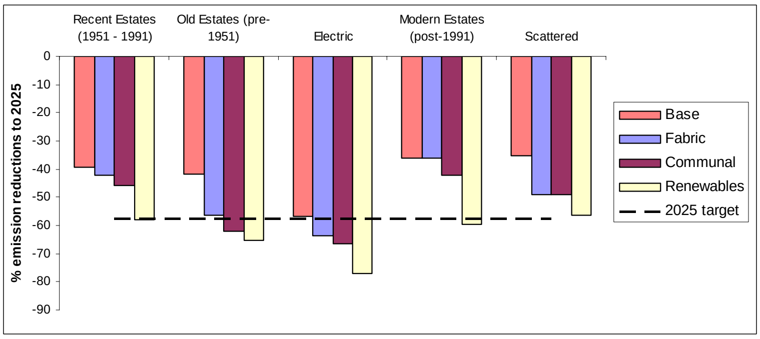

Figure 3.1.7 SD scenario: CO2 emission reductions to 2025 by stock type

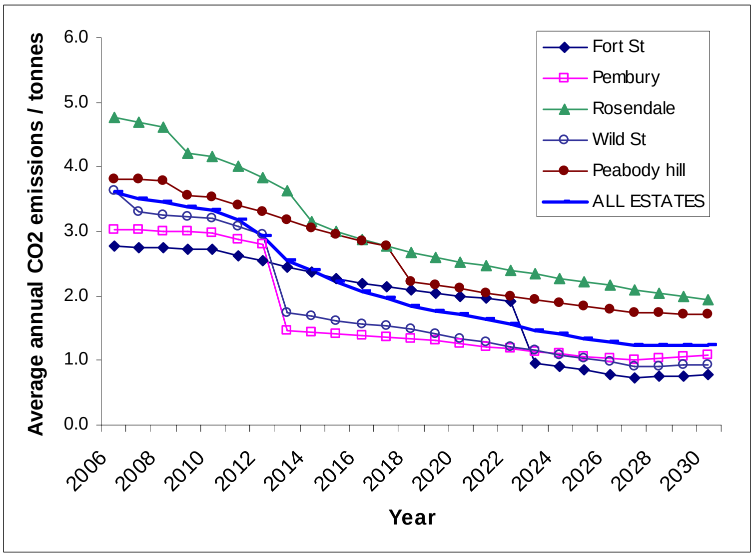

Figure 3.1.8 SD scenario, Renewables approach: CO2 emissions to 2030 for 21st Century Community estates

The refurbishment measures leading to these results are: PV and solar thermal being installed on each estate except Wild St and Rosendale (which are in conservation areas); CHP being installed on Wild St and Pembury, whilst Fort St receives district heating; Pembury receiving external insulation, whilst Wild St and Fort St receive ongoing internal insulation improvements in void dwellings.

3.2. Resident Costs

Results for baseline annual fuel costs are reported first and compared to UK average levels. Changes in costs to 2030 are then reported for each scenario, followed by a discussion on the prevalence of fuel poverty.

3.2.1. Baseline costs

Due to recent increases in fuel costs, baseline costs are calculated for 2008, not 2006. Fuel costs per resident in 2008 follow a similar trend to carbon emissions, being greater in older Peabody stock, and greater on electrically-heated estates, due to the relatively high unit cost of energy from electricity. Average annual UK fuel costs are shown for comparison, which are taken as £1317 per dwelling based upon British Gas standard tariffs (BBC News 2008), giving average costs per resident of £573. Fuel costs per resident are below the UK average on all estates, although these costs will represent a greater fraction of resident income on Peabody estates due to below-average incomes amongst Peabody residents.

Average costs by stock type (table 3.3) indicate that costs per resident are lowest on Recent and Modern estates, being less than half of the UK average, whilst costs are highest on Old estates, due to greater needs for space heating, less efficient boilers and a fraction of homes still using electric heating. Even on Old estates though, costs are some way below the UK average.

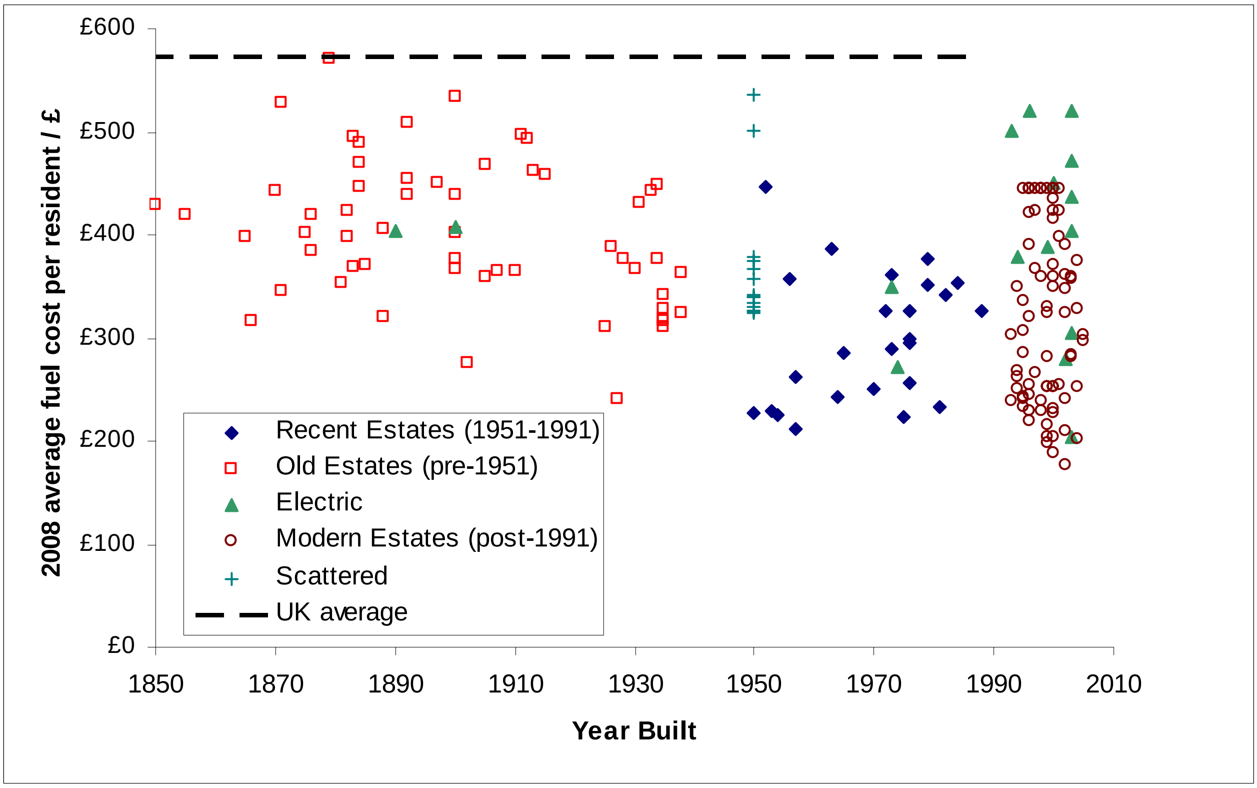

Figure 3.2.1 Baseline resident fuel costs by estate and stock type

Classification	Average 2008 cost per dwelling	Average 2008 cost per resident
Recent Estates (1951 - 1991)	£605	£259
Old Estates (pre-1951)	£715	£394
Electric	£651	£338
Modern Estates (post-1991)	£577	£260
Scattered	£684	£309

Table 3.3 Baseline resident fuel costs by stock type

3.2.2. Changes in costs

In 2030, average fuel costs have increased in real terms in each scenario (figure 3.2.2). Fabric improvements lead to reduced costs relative to the Base approach, with this reduction ranging from £90 in the KLO scenario to £130 in the BD scenario. However these reductions are a relatively small part of total fuel costs, indicating the strong influence of other energy use on fuel costs.

Communal measures make an insignificant difference, due to the assumption that energy is sold to residents at a price that leaves them no worse off than they would be if buying gas and electricity from utility companies. Solar thermal installations lead to a small further reduction in costs. PV installations have no impact, as it is assumed that all electricity generated is exported.

The figures and percentage increases shown in table 3.4 indicate the extent of the increases, which are most marked in the BD scenario. Despite significant increases in fuel costs in this scenario (such as gas prices approximately doubling by 2030 relative to 2008 levels), the overall impact on resident bills is reduced due to more efficient heating systems and reduced demand.

The impact of fabric measures is demonstrated in figure 3.2.3, where the gap between average fuel costs between older and more modern estates has been greatly reduced.

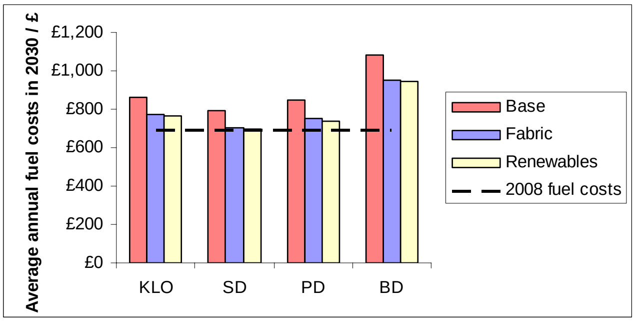

Figure 3.2.2 Average fuel costs in 2030 by scenario

	KLO	SD	PD	BD
Base	£862 (+14%)	£792 (+14%)	£849 (+22%)	£1,081 (+56%)
Fabric	£775 (+12%)	£702 (+1%)	£752 (+8%)	£955 (+38%)
Communal	£776 (+12%)	£701 (+1%)	£750 (+8%)	£955 (+38%)
Renewables	£769 (+11%)	£694 (+0%)	£741 (+7%)	£943 (+36%)

Table 3.4 Average fuel costs in 2030 by scenario

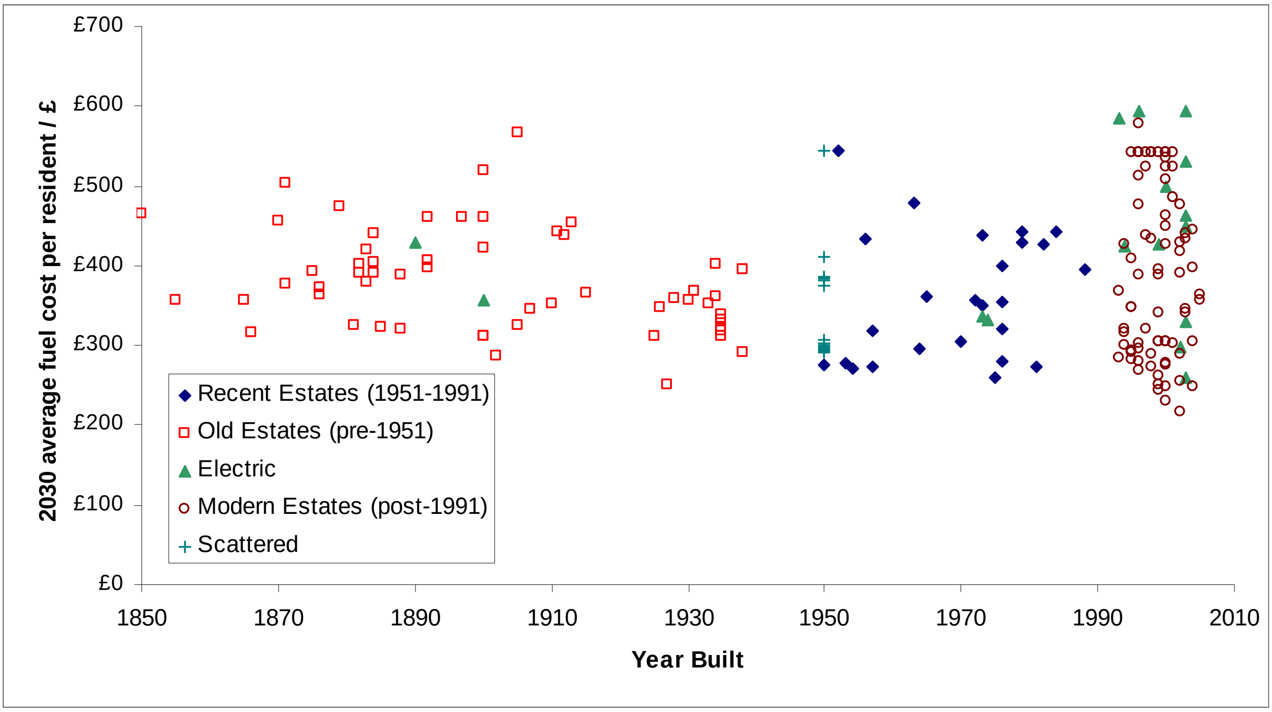

Figure 3.2.3 SD scenario, Fabric approach: Average fuel costs per resident in 2030

3.2.3. Fuel poverty

In a context of potentially increasing fuel costs, fuel poverty is an important consideration when considering refurbishment of social housing.

A household is defined as being in fuel poverty by the UK government if it needs to spend more than 10% of its total income on fuel for the home. A statutory target exists to eliminate fuel poverty in English social housing by 2010, and in all housing by 2016, though current trends point towards both targets being missed (NEA and Energy Action Scotland 2008).

In contrast to the Government definition, groups such as the fuel poverty charity National Energy Action (NEA) advocate an approach where disposable income (total income excluding housing costs) is considered instead of total income, although the same 10% threshold is used (NEA 2008). Using this approach leads to a much greater number of households defined as being in fuel poverty on Peabody estates, as the results below show.

Results are reported in this section for fuel poverty levels in 2008 and 2030. In chapter five the prospects for eliminating fuel poverty by 2016 through a rapid programme of insulation improvements is assessed. The methodology used for estimating levels of fuel poverty on Peabody estates is described in Appendix I.

Baseline results

In 2008, Peabody estates have an average of 3% of households in fuel poverty using the Total Income definition. This compares to an estimate of 4% of RSL households being in fuel poverty by the Government definition, from research conducted in 2007 (Energy Efficiency Partnership for Homes 2007).

Using the Disposable Income definition, 55% of Peabody households are in fuel poverty, a figure over ten times greater than that derived from the conventional definition. The discrepancy is due to the conventional definition allowing fuel bills to reach a higher level before declaring a household fuel-poor.

Considering the variation across stock types (table 3.5) it is clear that baseline fuel poverty levels are very low in Recent and Modern estates, relatively high on Old and electrically-heated estates and greatest on Scattered estates. The high fuel poverty levels on the latter estates are due to both a significant number of estates with solid walls requiring insulation and a number of estates with large floor areas relative to the number of residents.

2030 results

The results for 2030 show that reducing fuel poverty on Peabody estates is highly challenging in the context of increasing fuel prices assumed for each scenario.

By 2030, fuel poverty levels have increased in each scenario where the Base refurbishment approach is carried out. The increase is greatest in the BD scenario, which is defined by high fuel price increases (figure 3.2.4).

Fabric measures reduce fuel poverty levels by around 50% relative to the Base approach if the Total Income definition is used. This reduction leads to fuel poverty levels similar to those in 2008 for all scenarios except BD.

Using the Disposable Income definition, fabric improvements reduce fuel poverty levels by around 6% in each scenario (figure 3.2.5). Fuel poverty levels in 2030 still exceed 2008 levels for each scenario. This demonstrates that other fuel costs, besides those for space heating (which are reduced by fabric improvements) play a significant role in creating fuel poverty.

Classification	% households in fuel poverty: Total Income definition	% households in fuel poverty: Disposable Income definition
Recent Estates (1951 - 1991)	0.2%	42%
Old Estates (pre-1951)	4.2%	62%
Electric	2.5%	54%
Modern Estates (post-1991)	0.2%	43%
Scattered	6.5%	63%

Table 3.5 Baseline fuel poverty levels by stock type

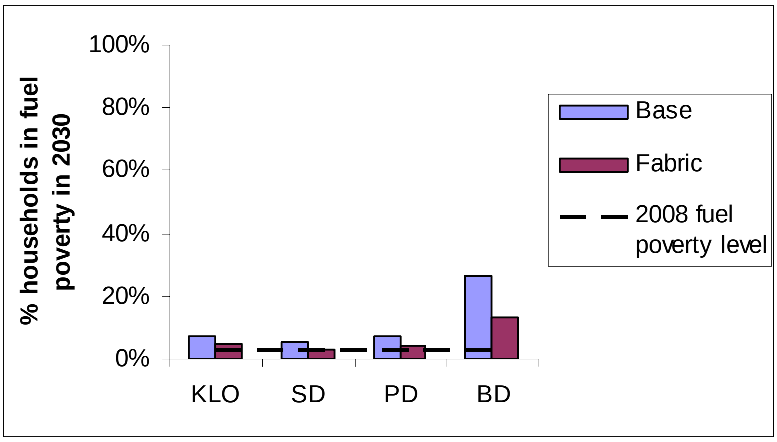

Figure 3.2.4 Fuel poverty levels in 2030 using Total Income definition

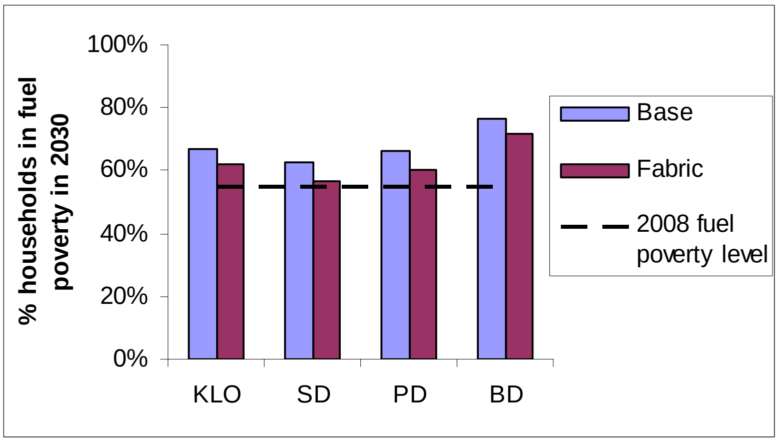

Figure 3.2.5 Fuel poverty levels in 2030 using Disposable Income definition

Reductions in demand for energy are shown to reduce fuel poverty levels, playing a part in the lower 2030 fuel poverty levels in the SD and PD scenarios relative to the KLO and BD scenarios respectively.

Fuel poverty levels in 2030 for different stock types are contrasted in table 3.6 using the SD scenario, which is representative of the trends in all scenarios. It is clear that fabric improvements greatly reduce the significant differences between fuel poverty levels in different stock types that were present in 2008. For estates with electric heating, this is due to the assumption that gas heating is installed as part of the programme of fabric measures.

Classification	% households in fuel poverty by Total Income definition: Base approach	% households in fuel poverty by Total Income definition: Fabric approach	% households in fuel poverty by Disposable Income definition: Base approach	% households in fuel poverty by Disposable Income definition: Fabric approach
Recent Estates (1951 - 1991)	2%	2%	59%	59%
Old Estates (pre-1951)	6%	3%	70%	62%
Electric	16%	4%	70%	64%
Modern Estates (post-1991)	2%	2%	60%	60%
Scattered	7%	4%	71%	65%

Table 3.6 SD scenario: 2030 fuel poverty levels by stock type

3.3. The financial impacts of refurbishment

The financial impacts of refurbishment are assessed in a number of ways. Firstly, the net energy-related expenditure for Peabody up to 2030 is reported, alongside the capital costs for each refurbishment approach.

In addition, the net present value (NPV) of each refurbishment approach (relative to the NPV of Peabody's planned refurbishment approach) is given. This is calculated both for Peabody considered alone and Peabody and its residents considered as a whole.

Finally, strategies for meeting the extra costs that more extensive refurbishment approaches require are discussed.

3.3.1. Net expenditure to 2030

Figures for net expenditure from 2011 to 2030 on energy-related equipment and services for each scenario are given below, taking into account all cash inflows and outflows over that period (table 3.7). The results demonstrate that for each refurbishment approach that goes beyond the base approach, net expenditure is increased. In addition, refurbishment costs are greater in the KLO and BD scenarios, where there is less grant support for insulation and renewables, lower reductions in installation costs for renewables and less financial support for micro-generation.

To illustrate the impact of refurbishment approaches on net expenditure, the breakdown of expenditure and income is shown below for the SD scenario (figure 3.3.1 and table 3.8). The spending breakdown for other scenarios is shown in Appendix III.

This breakdown indicates that for the Base approach, the vast majority of expenditure is on individual gas boilers, with over £110m being spent from 2011 to 2030 on their maintenance and replacement. Expenditure on other servicing options (electric storage heaters, existing communal heating systems and gas cooker maintenance) contributes a further £5.6m. Planned double-glazing installations over the considered period cost £31.1m.

The extra expenditure for the Fabric approach is roughly equally split between four types of measure: further double-glazing installations; external wall insulation; internal insulation measures; other fabric measures, primarily extractor fans. In the SD scenario a significant fraction of this extra expenditure is paid for by grant funding.

The Communal approach differs from the Fabric approach through significantly reduced spending on gas boiler maintenance and replacement. This saving is exceeded though by spending on communal heating to replace individual gas boilers, with spending related to CHP installations making the greatest contribution. Despite an income being generated for Peabody through selling heat and electricity to residents, this is insufficient to offset the increased capital costs, so overall expenditure exceeds expenditure in the Fabric approach.

The principal difference between the Renewables approach and the Communal approach is the considerable extra spending on PV installations. PV maintenance costs and solar thermal costs have a relatively minor additional impact (table 3.8). This spending is partially offset by income from exporting electricity to the grid, but still leads to a significant increase in net expenditure for Peabody.

	Keeping the Lights On	Sustainable Development	Power Down	Breaking Down
Base	£148m	£148m	£148m	£149m
Fabric	£215m	£195m	£191m	£214m
Communal	£232m	£212m	£204m	£230m
Renewables	£330m	£269m	£274m	£327m

Table 3.7 Net expenditure to 2030 by scenario

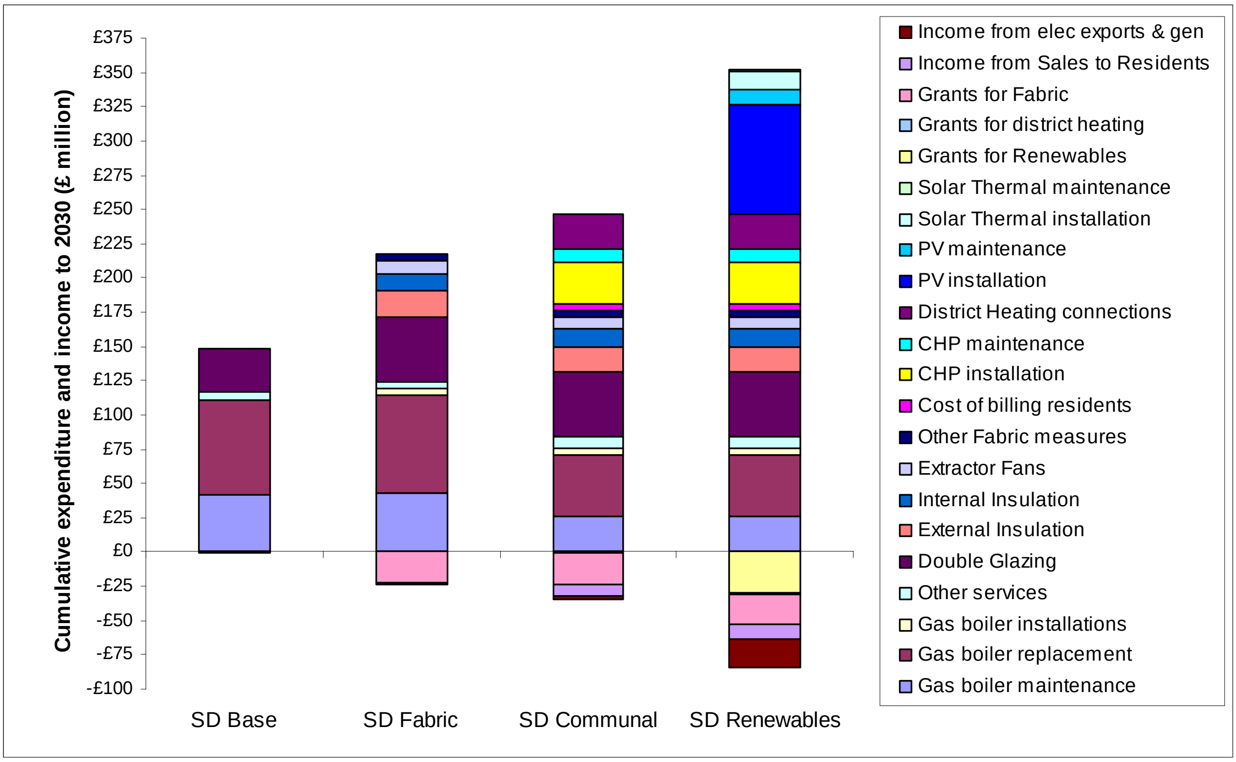

Figure 3.3.1 SD scenario: Breakdown of Peabody costs

	Base	Fabric	Communal	Renewables
EXPENDITURE				
Gas boiler maintenance	£41,613,506	£43,097,839	£26,450,185	£26,450,185
Gas boiler replacement	£69,453,528	£71,930,900	£44,145,731	£44,145,731
Gas boiler installations	£0	£4,800,767	£4,800,767	£4,800,767
Other services	£5,646,018	£4,894,356	£8,455,045	£8,455,045
Double glazing	£31,113,825	£46,986,677	£46,986,677	£46,986,677
External insulation	£0	£18,844,376	£18,844,376	£18,844,376
Internal insulation	£0	£12,875,808	£12,875,808	£12,875,808
Extractor fans	£0	£9,249,184	£9,249,184	£9,249,184
Other fabric measures	£0	£4,214,700	£4,214,700	£4,214,700
Cost of billing residents	£0	£648,700	£4,499,508	£4,499,508
CHP installation	£0	£0	£31,315,992	£31,315,992
CHP maintenance	£0	£0	£9,730,698	£9,730,698
District heating connections	£0	£0	£24,800,250	£24,800,250
PV installation	£0	£0	£0	£80,230,778
PV maintenance	£212,148	£212,148	£212,148	£10,810,356
Solar Thermal installation	£0	£0	£0	£12,948,744
Solar Thermal maintenance	£0	£0	£0	£2,029,086
INCOME				
Grants for renewables	£0	£0	£0	-£29,400,431
Grants for district heating	£0	£0	-£1,053,530	-£1,053,530
Grants for fabric improvements	£0	-£22,487,005	-£23,540,535	-£23,540,535
Income from sales to residents	£608,642[1]	-£240,839	-£8,930,465	-£10,685,371
Income from electricity exports & generation	-£455,256	-£455,256	-£1,638,256	-£20,021,633
Total	**£148,192,412**	**£194,572,355**	**£212,471,812**	**£268,739,915**

Table 3.8 SD scenario: Breakdown of Peabody costs

[1] Peabody is making a loss by selling heat to residents in this case

3.3.2. Capital costs of refurbishment

There is considerable uncertainty around the capital costs involved in carrying out low-carbon refurbishments on existing dwellings. This is due to the small quantity of such refurbishments carried out to date and uncertainty about future changes in costs (Hinnells 2005; Killip 2008).

One of the few estimates available in the literature at present comes from the consultancy Energy for Sustainable Development (ESD), which has estimated a cost of £25,000 to £30,000 to achieve a 60% emission reduction for an average UK dwelling (T-Zero 2007).

There is little variation in capital costs for refurbishment across the four scenarios considered. The average costs from the four scenarios are shown in table 3.9, both for those dwellings treated and the stock as a whole. These costs are the full costs that would need to be met by Peabody, and are fully inclusive of VAT, consultancy costs and contingency costs.

The average costs are approximately £24,500 for treated homes, or an average of £15,400 across the entire stock (including untreated homes). For the Renewables approach, approximately 80% of the spending across the whole stock is equally split between fabric and renewables measures, with the remainder being spent on communal heating installations.

The expenditure for different types of stock is shown below using the SD scenario as a representative example (full costs are shown, prior to any grant funding). Fabric measures are most costly on Old estates and Scattered estates, which typically require solid wall insulation. Fabric measures are also costly on Electric estates where it is assumed that electric storage heating is replaced with gas central heating.

Communal costs vary little, with discrepancies due to the extent to which the more capital-intensive district heating connections are carried out instead of gas-fired CHP installations. Renewables costs depend largely on the available roof space per dwelling for each estate type. This is greater by far on scattered estates, which are more likely to be low-rise and have greater floor areas, leading to the high installation costs.

3.3.3. NPV of refurbishment

Description of approach

The Net Present Value (NPV) of approaches is a measure of their financial impact, taking into account that costs and benefits over the timescale under consideration (20 years) are typically given greater weight the earlier they occur (HM Treasury 2007). For a description of NPV, see section 1.14 in appendix I.

	Average per dwelling treated	Average for all estates
Fabric	£7,995	£6,257
Communal	£5,862	£3,096
Renewables	£10,665	£6,038
TOTAL	£24,521	£15,391

Table 3.9 Capital costs of refurbishment

Classification	No. Units	Average cost per home treated			TOTAL
		Fabric measures	Communal measures	Renewables measures	
Recent Estates (1951 - 1991)	2304	£3,057	£5,508	£10,300	£18,865
Old Estates (pre-1951)	8210	£8,379	£6,028	£6,501	£20,908
Electric	456	£7,101	£7,690	£8,742	£23,533
Modern Estates (post-1991)	2351	£2,391	£7,632	£8,986	£19,009
Scattered	2981	£8,621	£5,096	£23,947	£37,664

Table 3.10 SD scenario: average capital costs by refurbishment approach

A positive NPV is typically viewed as a sign that an investment is beneficial and should be made, whilst a negative NPV indicates an investment that should be avoided. For investments considered as part of this research, NPV values are calculated for the Fabric, Communal and Renewables approaches *relative to the Base approach*. Therefore they represent the extra monetary value that is generated by a particular more-extensive refurbishment approach.

NPV is calculated for both Peabody and its residents considered as a whole (referred to 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 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.

It is possible for an approach to have a positive NPV and a negative Peabody NPV. For example, this would occur if the financial benefits of refurbishment to residents outweighed the extra costs incurred by Peabody.

In this case, the positive NPV indicates that by redistributing the financial benefits between Peabody and its residents (for example by increasing rents in refurbished homes) a solution that financially benefits both parties should be attainable.

NPV Results

The results indicate that for each scenario modelled, the addition of each refurbishment package leads to a reduction in NPV (figure 3.3.2). This result is particularly pronounced where renewables are installed. This result contrasts with the positive NPV typically associated with low-cost measures such as cavity wall insulation or draught-proofing, where a payback on the initial investment is achieved within a small number of years.

High fuel prices and grant funding significantly increase the NPV of fabric measures, by increasing resident fuel cost savings and reducing Peabody spending on refurbishment respectively. This gives an NPV that is closest to zero in the PD scenario.

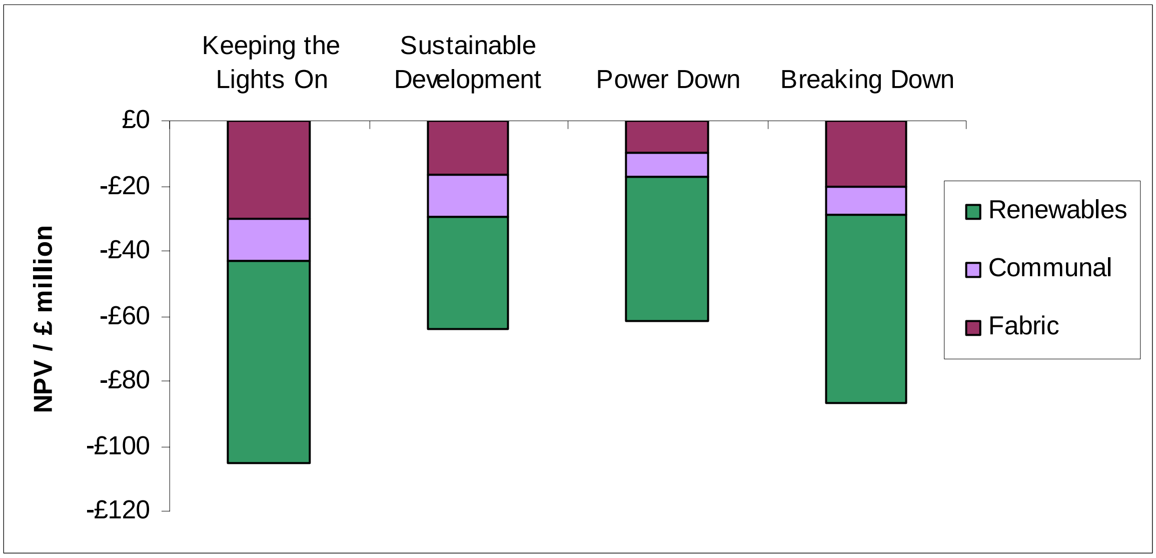

Figure 3.3.2 NPV of refurbishment approaches by scenario

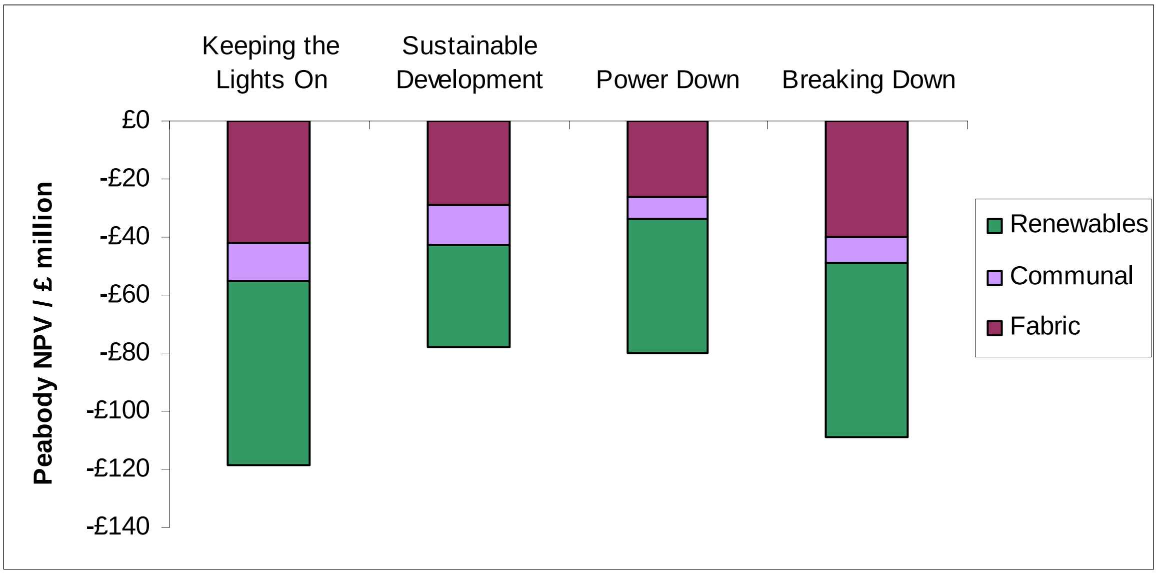

Figure 3.3.3 Peabody NPV of refurbishment approaches by scenario

This result for the PD scenario demonstrates that through, for example, a combination of higher fuel costs and higher grant funding, the social case for the Fabric approach could exist.

The assumed discount rate is also a significant factor, with the lower discount rates assumed in the high fuel price scenarios putting greater weight on future savings achieved by initially capital-intensive measures. This effect leads to a greater NPV for the PD and BD scenarios relative to SD and KLO respectively.

Grant funding also significantly affects NPV for the Renewables approach, with costs being lower in the PD and SD scenarios due to the financial support assumed.

For approaches that meet the GLA’s carbon reduction target, NPV is negative in each case, indicating a lack of a social case for the required measures. As a result, if rent increases were used to fund carbon reduction measures, they would outweigh the fuel bill savings, leaving residents worse off overall.

The PD scenario is closest to having a financial case for refurbishment, as the target can be achieved without installations of renewables. However, further fuel price increases or increased financial support for refurbishment would be needed to give a positive NPV.

Peabody NPV results

Results for NPV for Peabody considered alone (figure 3.3.3) are similar to the NPV results described above, with the only significant difference being the reduced NPV for the Fabric approach (as the financial benefits for residents are no longer taken into account). The impact of Communal and Renewables approaches mirrors that for NPV as described above, as these have little impact on resident fuel costs.

Peabody NPV for the approaches that meet the GLA target are as follows: -£34 million for the Communal approach in Power Down; -£78 million for the Renewables approach in Sustainable Development; -£80 million for the Renewables approach in Power Down. Therefore, the refurbishment approaches that meet the GLA’s 2025 target have a detrimental financial impact for Peabody. This is despite the assumptions of considerable grant support for refurbishment and renewables in the PD and SD scenarios.

The finding that every approach has a negative impact on Peabody NPV indicates that of the approaches considered, the current approach to refurbishment is the least cost option for Peabody over the long term.

3.4. Summary

Four refurbishment approaches have been considered for four scenarios and the resultant carbon emissions, resident fuel costs and financial impacts for Peabody have been quantified.

The results indicate that the carbon reduction target for 2025 is only achieved in the Sustainable Development or Power Down scenarios. Therefore even where the most comprehensive refurbishment approach is used, the GLA target is not achieved in the Keeping the Lights On and Breaking Down scenarios.

These results indicate the need for change external to Peabody — such as reduced energy demand and the availability of low-carbon energy — for deep carbon emission cuts to be achieved.

The target is achieved through the Communal and Renewables approaches for Power Down, and only for the Renewables approach for Sustainable Development. These results highlight that even with substantial societal changes leading to carbon emission reductions, the refurbishment work that needs to be carried out by Peabody still may be considerable.

For all scenarios, the net present value for Peabody of every refurbishment approach is negative, indicating that they cannot be carried out unless extra funding is secured.

The net present value for Peabody and its residents considered together is also negative in every case. This indicates that overall savings for residents are outweighed by the increased costs of refurbishment. As a result, if rents were raised to cover these refurbishment costs, residents would be worse off overall in each scenario.

Future fuel poverty levels vary significantly depending on the level of fuel price increases assumed. For Peabody’s planned approach to stock refurbishment, fuel poverty levels increase in 2030 in all scenarios, with over 25% of households in fuel poverty in the Breaking Down scenario.

If solid wall insulation is installed across Peabody stock, the extent of fuel poverty in 2030 is approximately halved relative to the Base approach. For all scenarios except Breaking Down, this enables fuel poverty levels to be kept at similar levels to the present day.

4. SENSITIVITY ANALYSIS

The reliability of the model outputs reported in chapter three was explored by undertaking sensitivity analysis on the variables used in the model (such as discount rates, fuel costs, etc). This was done for four outputs of the model: reductions in carbon emissions to 2025, NPV, Peabody NPV and fuel poverty levels in 2030.

The results are intended to reveal both the most significant variables, which have the greatest influence on results if changed, and the robustness of the results, by identifying whether the conclusions described in chapter three are altered by changes in variables.

The impact of changes in values of variables was identified for each approach in each scenario. For each variable, a high and low alternative value was considered, chosen so as to represent the likely range of uncertainty of the value in question. A summary of the values used is given in Appendix IV.

In addition, the values required to give a desired result (such as meeting the 2025 target) for a number of key variables (such as resident energy demand) were calculated for each approach and each scenario. The approach used for this is given in Appendix V.

4.1. Carbon Emissions

4.1.1. Meeting the 2025 target

To assess the robustness of the conclusions on the achievement of the 2025 target, the maximum and minimum emission reductions identified through changes of variables were compared to the reductions achieved through the original assumptions. These results are shown in figure 4.1.1, with the maximum and minimum results for each approach and scenario shown using error bars on the graph.

The results show that the 2025 target is not achieved through the Base approach in any scenario. It is also not achieved through any approach in the KLO scenario, and can only potentially be achieved in the BD scenario through the Renewables approach. In the PD and SD scenarios, the results indicate a possibility that the 2025 target can be met through both Fabric and Communal approaches, though the former would be less likely to succeed in each case.

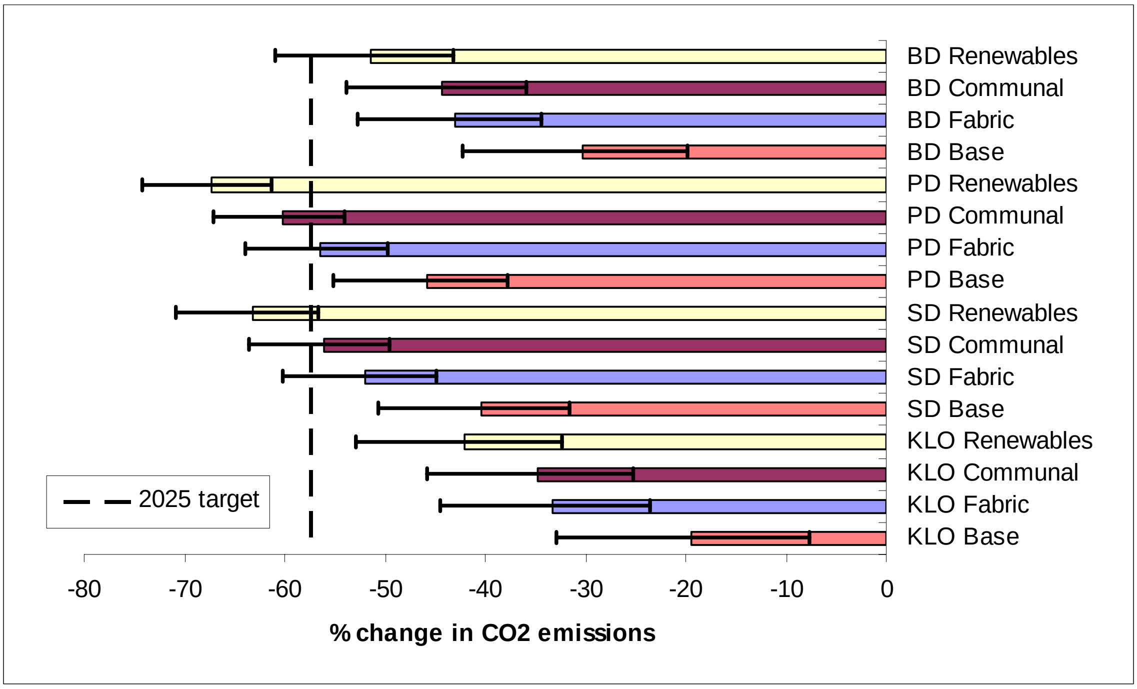

Figure 4.1.1 Sensitivity analysis for carbon emissions

The uncertainty around model results revealed by the sensitivity analysis highlights that the results are best considered in probabilistic terms. An approach that generates emission reductions that just achieve the 2025 target (a 57.4% reduction) could in practice (given the uncertainties in the model) achieve reductions above or below this figure. Assuming that the likelihood of emission reductions being above or below the calculated amount is equal, a 57.4% result can be thought of as indicating a 50:50 chance that the 2025 target is met.

It follows that the greater the difference between the calculated emission reductions and the 2025 target, the greater the confidence that the conclusion (of the target being met or missed) is accurate. A “good degree of confidence” of the target being met is defined here as achieving emission reductions such that no changes in an individual variable (using the sensitivity analysis values given in Appendix IV) leads to failure to meet the target. By this definition, the results above illustrate that only the Renewables approach in the PD scenario succeeds in meeting the 2025 target with a good degree of confidence.

4.1.2. Most significant variables

The tornado charts (figures 4.1.2 to 4.1.5) illustrate the effect of changing particular model variables for the Renewables approach. This approach was chosen as all possible refurbishment measures are applied, so any significant impacts of changing variables can be observed. The results displayed are just those that change the emission reduction results by at least 1%.

In each scenario the assumed change in energy demand is the most significant variable, followed by the assumed carbon intensity of electricity. The assumptions on the carbon intensity associated with displaced grid electricity and the effectiveness of insulation in reducing heat demand are also shown to be significant.

Other assumptions have a relatively low impact on results, indicating that the model results appear to be robust even if they are changed. This includes a number of assumptions for which there was some uncertainty, such as average floor areas, average window areas or heat demand per square metre.

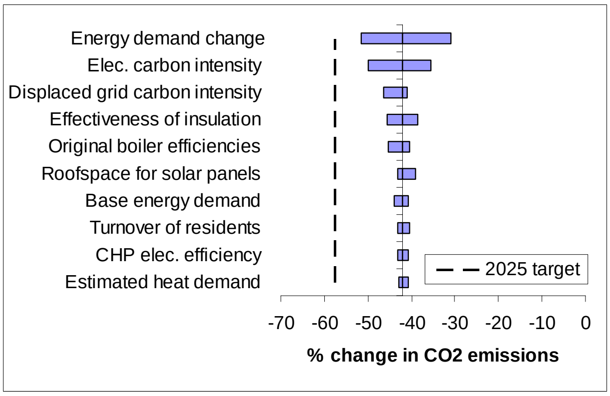

Figure 4.1.2 KLO Renewables sensitivity analysis for carbon emissions

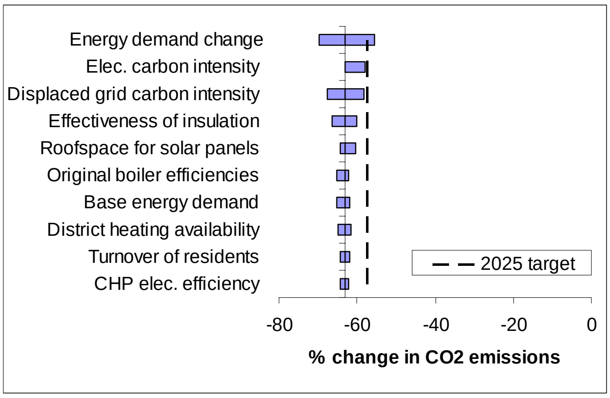

Figure 4.1.3 SD Renewables sensitivity analysis for carbon emissions

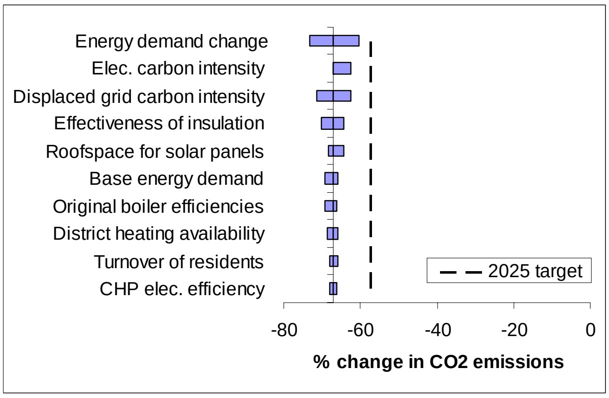

Figure 4.1.4 PD Renewables sensitivity analysis for carbon emissions

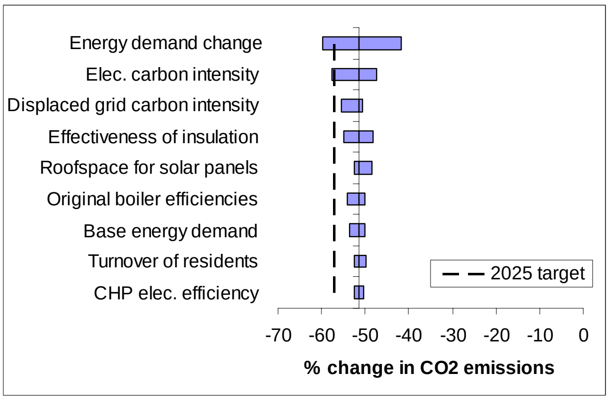

Figure 4.1.5 BD Renewables sensitivity analysis for carbon emissions

4.1.3. Values required to meet the 2025 target

Two key variables were identified through the above analysis: changes in energy demand from residents and the carbon intensity of grid electricity. For each variable, the values required to just allow the 2025 carbon reduction target to be met was calculated. This was done for each scenario, assuming that all other assumptions for the scenario in question remain unchanged.

Results for energy demand

The results for resident energy demand (table 4.1) indicate that reductions in demand required in each scenario to meet the 2025 target are greatest for the less extensive refurbishment approaches.

The figures can be compared to an estimated 33% potential saving in domestic energy use achievable without radical changes in householder circumstances (Sonderegger 1978) and reductions of 15%-25% achievable through feedback on energy use (Darby 2006).

This comparison makes the reductions in demand required to meet the 2025 target through Peabody's current planned refurbishment approach appear very challenging in each scenario.

Achieving the target through the Fabric approach appears more attainable for the SD and PD scenarios. However, it is reliant on demand for electricity (which has been increasing annually by almost 2% for many years) declining significantly by 2025.

The results show that the Renewables approach can be effective in the SD and PD scenarios even if demand for energy remains essentially unchanged.

There is some uncertainty about the correlation between increased fuel costs and reduction in demand for energy. If the fuel price increases considered in the BD scenario lead to overall reductions in energy demand of 15% or beyond, then the 2025 target could potentially be achieved in this scenario.

Results for carbon intensity of electricity

The results for carbon intensity of grid electricity demonstrate a significant difference between scenarios and approaches.
The Base approach is insufficient in each scenario except Power Down where grid electricity needs to be almost entirely zero-carbon for the GLA's target to be achieved. The target is also not achieved in the KLO scenario, except by a near zero-carbon grid for the Fabric approach. The Communal and Renewables approaches are insufficient in this scenario, since where grid carbon intensity is very low, the Communal approach leads to an increase in emissions, and the impact of the Renewables approach is greatly decreased.

The results demonstrate potential for the target to be achieved if the radical reductions in carbon intensity of the grid currently called for by Government are achieved: for example, a 56% reduction (giving a grid intensity of 0.23) would make both the Communal approach in SD and the Fabric approach in PD successful.

Approach	Keeping the Lights On	Sustainable Development	Power Down	Breaking Down
Base	-41%	-35%	-35%	-41%
Fabric	-28%	-20%	-20%	-28%
Communal	-26%	-13%	-13%	-26%
Renewables	-15%	+1%	+1%	-15%

Table 4.1 Resident energy demand changes to meet the 2025 target

Approach	Keeping the Lights On ($kgCO_2/kWh$)	Sustainable Development ($kgCO_2/kWh$)	Power Down ($kgCO_2/kWh$)	Breaking Down ($kgCO_2/kWh$)
Base	N/A	N/A	0.016	N/A
Fabric	0.027	0.141	0.233	0.101
Communal	N/A	0.230	0.323	0.003
Renewables	N/A	0.381	0.764	0.262

Table 4.2 Carbon intensity of grid electricity in 2025 to meet the GLA's target

4.2. Net Present Value for Peabody

4.2.1. Achieving zero Peabody NPV

The sensitivity analysis for Peabody NPV (figure 4.2.1) indicates that the conclusion that Peabody NPV is negative for each approach and scenario considered appears to be robust. This is despite significant uncertainty in the cost assumptions used (for example, an uncertainty of £26 million for the Renewables approach in the KLO scenario.

4.2.2. Most significant variables

The ten most significant variables for Peabody NPV are shown in the following tornado charts (figures 4.22 to 4.25), and are broadly similar across the four scenarios.

The two most significant factors are costs for solar PV and available roof space for solar panels, reflecting the high costs of installing photovoltaics. Levels of grant funding have a significant impact, both in terms of low carbon zone funding and grants for renewables. CHP costs have significant uncertainty attached.

The size of terminal values is a methodological assumption with a significant impact. This relates to the value ascribed to technologies that have further years of their expected lifespan remaining in 2030.

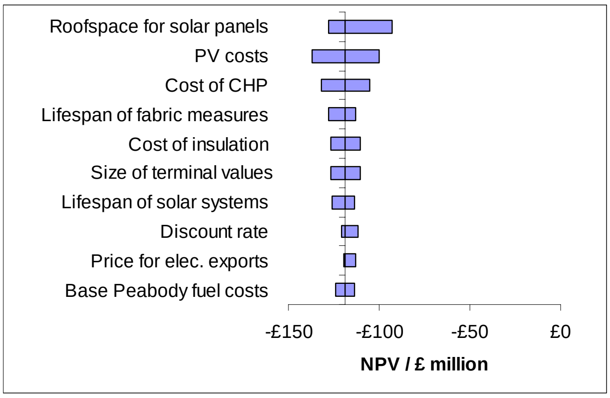

Figure 4.2.2 KLO Renewables sensitivity analysis for Peabody NPV

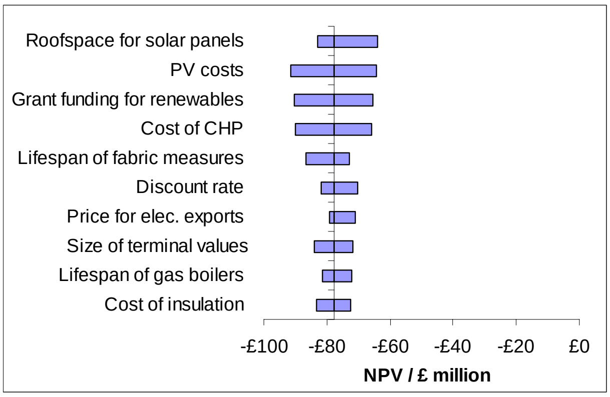

Figure 4.2.3 SD Renewables sensitivity analysis for Peabody NPV

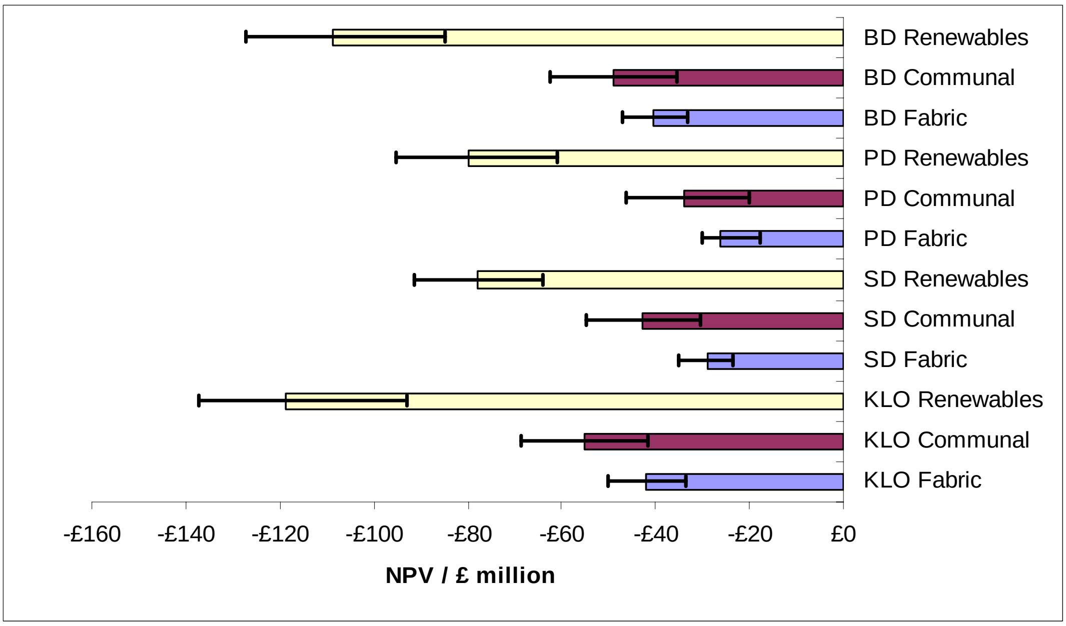

Figure 4.2.1 Sensitivity analysis for Peabody NPV

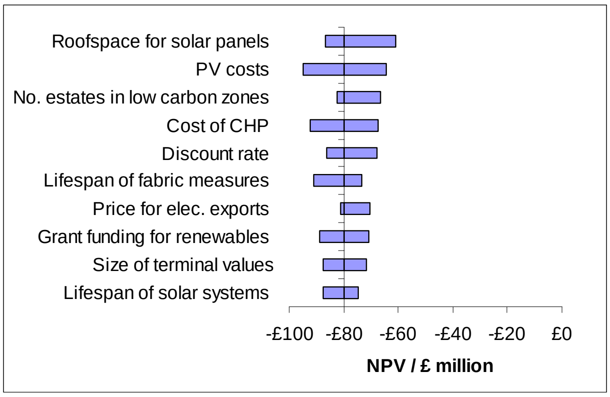

Figure 4.2.4 PD Renewables sensitivity analysis for Peabody NPV

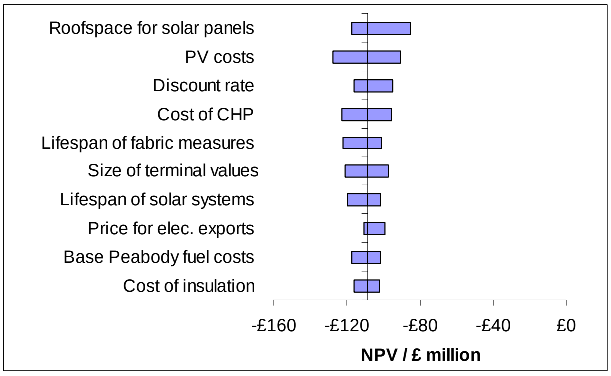

Figure 4.2.5 BD Renewables sensitivity analysis for Peabody NPV

4.2.3. Values required for zero Peabody NPV

The values required for four broad scenario assumptions to give a zero NPV for Peabody were calculated. These were the assumed discount rate, changes in fuel costs, costs of all refurbishment measures, and costs of alternative measures (technologies not used in the Base approach, such as CHP or solar thermal). The method used in each case is given in Appendix V.

The results demonstrate that achieving a positive NPV for Peabody through changing any of these variables is not viable, as the values required are extremely unlikely to be realisable.

The results for the four scenarios include: annual fuel cost increases in the range 19% to 30%; refurbishment costs being reduced by 78% to 98%; costs for alternatives being reduced by 49% to 77%; a discount rate between -3.5% and -7.7%; grant funding covering 65% to 89% of costs.

This result supports the conclusion outlined in chapter three that funding would be needed from Peabody's own internal resources to fund significant refurbishment, which may need to be derived from stock sales or rent increases.

4.3. NPV for Peabody and its residents

4.3.1. Achieving zero NPV

The sensitivity analysis results indicate that a zero NPV is not likely for any of the scenarios considered, despite the significant uncertainty in some of the variables used (figure 4.3.1).

The PD scenario is closest to achieving a non-negative NPV, with the results for the Fabric and Communal approach both being relatively close to zero. Changes in assumptions for this scenario, such as fuel costs rising to higher levels than those assumed could give a positive NPV for these approaches.

For PD, the Communal approach meets the 2025 target and the Fabric approach is close to doing so, so this result indicates that there is potential for refurbishment of Peabody stock to meet the 2025 target and be cost-effective in a context of high fuel prices, low energy demand and low carbon grid intensity.

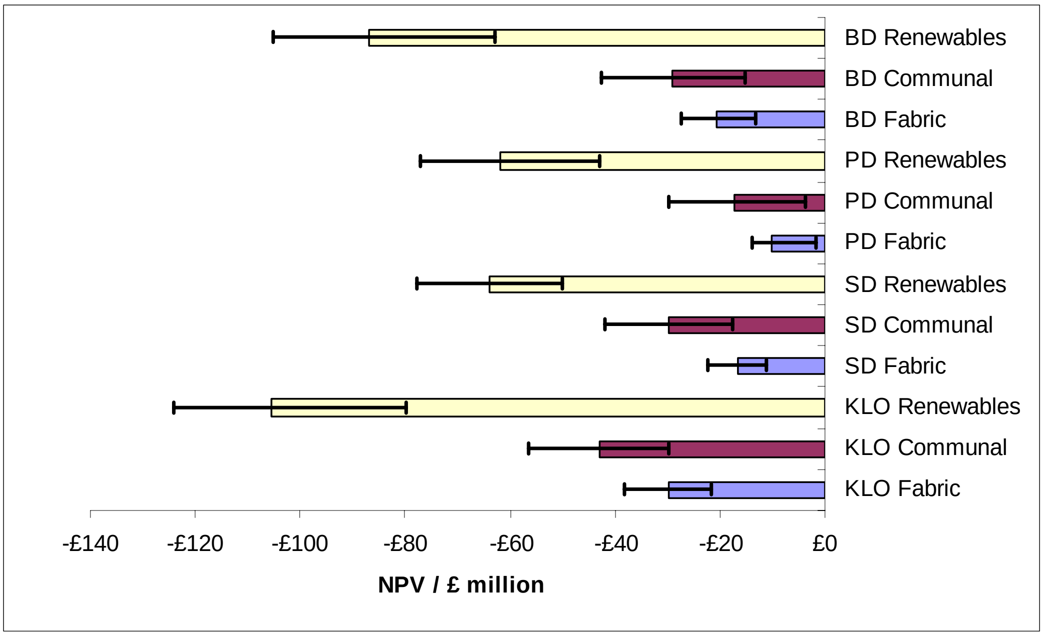

Figure 4.3.1 Sensitivity analysis for NPV

4.3.2. Most significant variables

The most significant variables for NPV for the Renewables approach are virtually identical in order and magnitude as described above. The graphs show the changes for the fabric approaches and communal approaches where a zero NPV is close to being achieved (figure 4.3.2 and figure 4.3.3).

For the Fabric approach in the PD scenario, a number of variables can potentially take the NPV close to zero, with potential grant funding for “low carbon zones” being dominant. The dominant factors are similar for the Communal approach, although the uncertainty relating to the costs associated with CHP is shown to have a significant impact.

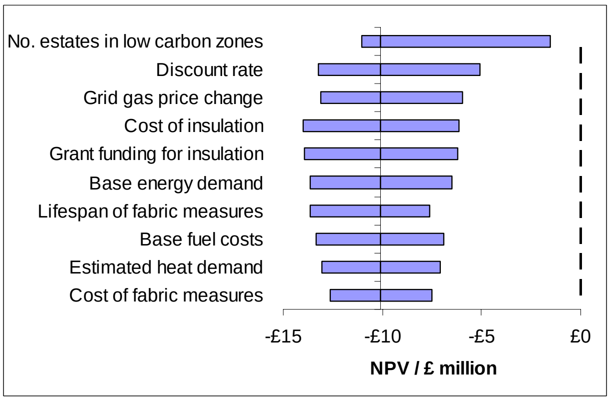

Figure 4.3.2 PD Fabric sensitivity analysis for NPV

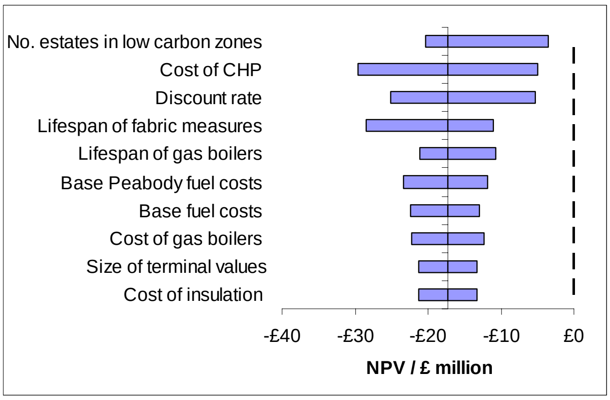

Figure 4.3.3 PD Communal sensitivity analysis for NPV

4.3.3. Values required for zero NPV

As for Peabody NPV above, the changes required for four variables (discount rate, fuel costs, costs of all refurbishment measures, costs of alternative measures and grant funding) to give a zero NPV were calculated. The results indicate that meeting the 2025 target in a way that is cost-effective for Peabody and its residents considered as a whole is highly challenging.

The values required for the three approaches that meet the 2025 target are shown in table 4.3.

	PD Communal	PD Renewables	SD Renewables
Discount Rate	-0.7%	-3.0%	-2.8%
Fuel Costs	+7% per annum	+11% per annum	+12% per annum
Costs of all measures	-40%	-61%	-63%
Costs of alternatives	-25%	-49%	-52%
Grant funding	56%	65%	69%

Table 4.3 Values required to meet 2025 target with zero NPV

The results for the Communal approach in the PD scenario show that if the costs of CHP and district heating are 25% less than the amounts assumed in this research (which is a possibility due to the significant uncertainty that exists), then that approach could be cost effective overall.

The other figures for this approach are likely to be too extreme to be realistic. For example, a 7% per annum fuel cost increase leads to 2030 costs over 4.5 times greater than 2008 levels. The figures for both Renewables approaches are likely to be outside the bounds of possibility.

4.4. Fuel Poverty

4.4.1. Results

The sensitivity analysis results for fuel poverty indicate significant uncertainty in the levels of fuel poverty on Peabody estates (figure 4.4.1). This is due in part to the nature of household incomes where relatively small changes in fuel costs can create significant increases in fuel poverty levels (Energy Efficiency Partnership for Homes 2007).

Despite this uncertainty, the conclusion that more Peabody residents are in fuel poverty in 2030 than in 2008 in the high fuel cost Breaking Down scenario still holds. The results reveal a risk of the majority of Peabody households being in fuel poverty if high fuel prices are combined with no solid wall insulation improvements. For the lower fuel cost scenarios, fabric improvements could lead to fuel poverty being virtually eliminated on Peabody estates.

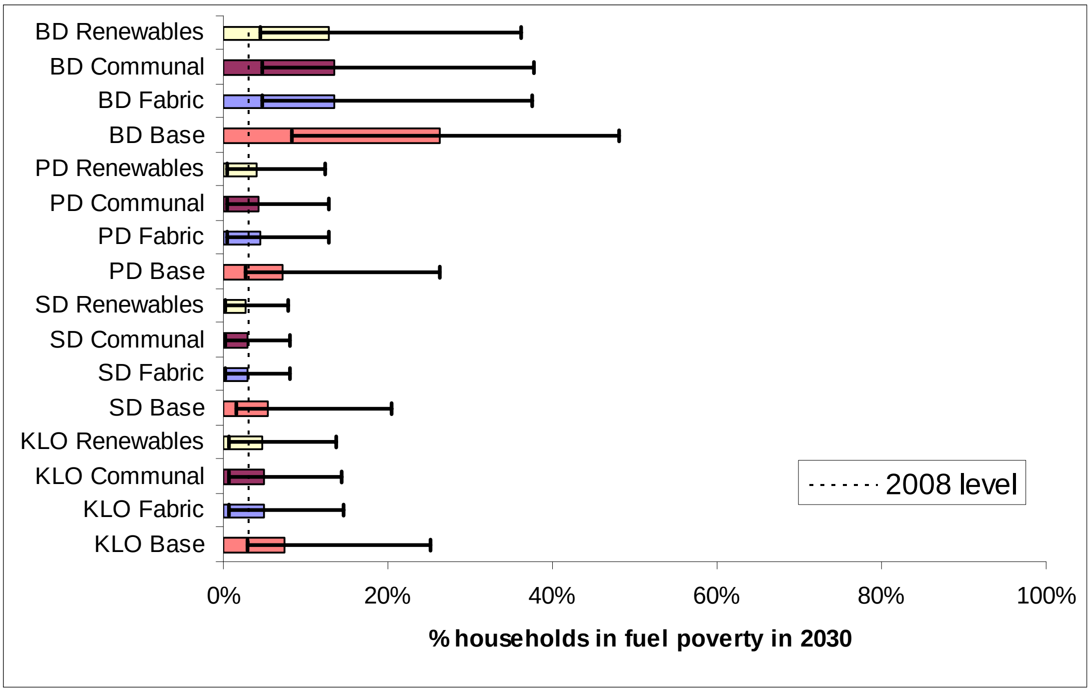

Figure 4.4.1 Sensitivity analysis for fuel poverty

4.4.2. Most significant variables

The most significant variables affecting fuel poverty levels are the same for each scenario. The effects are illustrated here for the KLO and PD scenarios (figures 4.42 and 4.43).

In each case, as would be expected, changes in fuel prices have the greatest impact. The results are also sensitive to the original model assumptions for energy demand, heat demand and the assumed impact of insulation measures. Despite the relatively low uncertainty in fuel costs in 2008, varying this assumption has a significant impact on the calculated fuel poverty levels for 2030.

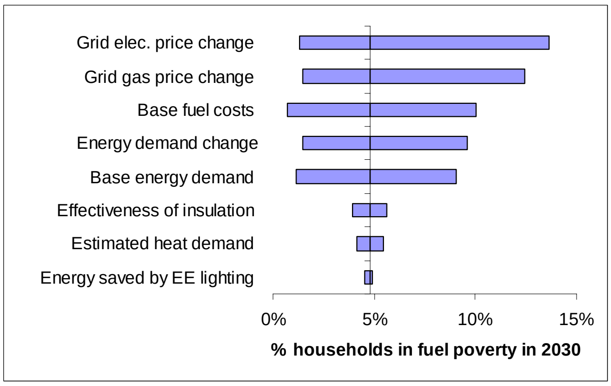

Figure 4.4.2 KLO Renewables sensitivity analysis for fuel poverty

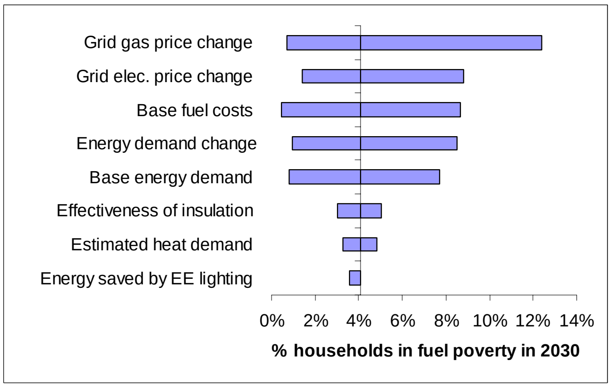

Figure 4.4.3 PD Renewables sensitivity analysis for fuel poverty

4.4.3. Values required for zero fuel poverty

The analysis above identifies fuel costs and demand for energy as two variables that significantly affect fuel poverty levels and which could change markedly over future years. The values required for these variables to eliminate fuel poverty on Peabody estates were calculated for each approach and scenario (table 4.4).

“Zero fuel poverty” is best interpreted here as fuel poverty levels being very close to zero, as given the great variance in average fuel costs between households, there are likely to be some households in fuel poverty even where average fuel costs are some way below 10% of average income levels.

The results for energy demand indicate that challenging reductions are required in each scenario to eliminate fuel poverty. The lowest reductions are required in the KLO scenario, although this requirement contradicts strongly with the increasing demand for energy assumed as a default in that case.

The results for fuel costs indicate potential for fuel poverty to be eliminated on Peabody estates if fuel prices remain at comparable levels to the present day to 2030. Due to the assumed reduction in demand for energy in the PD scenario, fuel costs can increase by up to 20% and still allow for fuel poverty to be eliminated.

If fabric improvements are carried out, the maximum levels of both energy demand and fuel prices that can still be associated with the elimination of fuel poverty are increased significantly.

	KLO	SD	PD	BD
Energy Demand: Base	-33%	-41%	-50%	-56%
Energy Demand: Fabric	-20%	-31%	-42%	-49%
Fuel Costs: Base	-31%	-9%	+3%	-18%
Fuel Costs: Fabric	-23%	+6%	+20%	+2%

Table 4.4 Energy demand and fuel cost changes required to eliminate fuel poverty

4.5. Summary

The sensitivity analysis undertaken aimed to identify the most significant assumptions affecting model outputs and to assess the robustness of this report's findings given the inevitable uncertainty within the model.

The results indicate that for carbon emissions, the two factors that have the greatest potential to affect the results are the carbon intensity of grid electricity and resident demand for energy.

If greater reductions in either the carbon intensity of grid electricity or resident energy demand can be achieved up to 2025, the GLA target could potentially be achieved through fabric improvements alone. However, the conclusion that the GLA's 2025 target is not achieved through Peabody's planned refurbishment approach appears to be robust.

The analysis reveals that the carbon reduction estimates arising from the Peabody Energy Model can be usefully understood as indicating a likelihood of success of meeting the 2025 target. Modelled reductions at exactly the level called for by the target (57.4%) can be understood as broadly indicating a 50% level of confidence that the target is met.

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.

The results also reveal a small but significant chance of achieving the 2025 target through the Fabric approach in the PD and SD scenarios and through the Communal approach in the SD scenario. These approaches are each associated with considerably lower refurbishment costs.

Where Peabody NPV is considered, despite significant uncertainty in its magnitude, the conclusion that it is negative for each refurbishment approach considered appears to be robust. The assumptions that have the greatest impact on this figure are those that affect the most costly refurbishment measures, such as available roof space for PV, CHP costs and grant funding for low carbon zones.

For NPV for Peabody and its residents considered together, a positive NPV is not achieved through any changes to model assumptions. The approaches which are closest to achieving a positive NPV are the Fabric and Communal approaches for PD, the latter of which meets the 2025 target.

This result therefore indicates potential for the 2025 target to be achieved cost-effectively if fuel costs increase beyond the levels assumed in the sensitivity analysis for Power Down.

Fuel poverty levels reported are shown to have considerable uncertainty attached. In the high fuel price Breaking Down scenario, they increase for all values considered. For other scenarios, the combination of fabric improvements and low fuel price increases is shown to lead to fuel poverty being virtually eliminated.

5. ANALYSIS OF RESULTS

In this chapter, the model results are explored so as to give a richer understanding of the impacts of each refurbishment approach and scenario considered.

This is done first by analysing how cost-effectively each of the approaches and individual measures considered reduce emissions. Then the implications are explored of changing a number of assumptions relating to approaches to refurbishment and a number of factors affecting the model results.

The results of this chapter are then used to devise the refurbishment approaches for each scenario reported in chapter six.

5.1. Cost-effectiveness of approaches and measures

This research considers four broad approaches, each of which consist of a combination of measures, such as the installation of solar PV or district heating. This section will consider the cost-effectiveness with which the considered measures and approaches reduce carbon emissions.

Cost-effectiveness at reducing emissions was assessed by calculating the change in both NPV and Peabody NPV for each tonne of CO_2 saved. The results therefore respectively indicate the overall cost-effectiveness at reducing emissions and the cost-effectiveness from Peabody's perspective alone.

This was carried out by contrasting each refurbishment option with a case which was identical save for the measure/approach not being applied.

Results for Peabody NPV

The results (table 5.1) indicate that every measure considered leads to a decrease in NPV for Peabody, implying that none of the options considered are financially attractive. The extent to which Peabody NPV is negative varies significantly between measures and scenarios.

	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
External insulation	-£410	-£517	-£217	-£334	-£48	-£202	-£359	-£550
Advanced Fabric	-£3,129	-£3,213	-£2,597	-£2,672	-£2,356	-£2,451	-£3,309	-£3,460
Communal	-£744	-£753	-£418	-£428	-£229	-£243	-£503	-£515
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
Heat-load-sized CHP (relative to Fabric)	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Heat-load-sized CHP (relative to Fabric, with no insulation in voids)	-£717	-£732	-£1,007	-£1,037	-£831	-£872	-£609	-£632
Renewables	-£1,002	-£1,019	-£565	-£582	-£735	-£759	-£932	-£962
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

Table 5.1 Change in Peabody NPV per tonne of CO_2 saved

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

The Fabric approach is shown to be more cost-effective than the Communal and Renewables approaches in each scenario. This result supports the decision taken to assume that this approach is carried out as a first step for all refurbishments.

Fabric improvements carried out in void dwellings are shown to be the most cost effective fabric improvement. If Peabody decants residents from their homes so that insulation can be installed, this is significantly less cost-effective than the alternative of insulating voids, but more cost-effective than CHP, solar thermal or solar PV.

The marginal cost of applying the Advanced Fabric approach in place of the Fabric approach is found to be considerable in all scenarios. This indicates diminishing returns in going beyond the more straightforward fabric measures of installing solid wall insulation, improved controls and extractor fans.

Of the communal heating measures, district heating connections are considerably more cost effective than CHP installations. This is despite capital costs being greater for district heating, and is due to assumed lower maintenance costs and the greater emission reductions achieved.

Installing larger CHP plant that runs only during the heating season to provide for estates' heat demand is considered as an alternative to insulating homes. The results indicate that insulating estates with a high heat demand is a more effective carbon reduction measure, even though this typically means gradually treating void dwellings as they become available. When compared to a Fabric approach where insulation in voids is not carried out, the addition of heat-load-sized CHP is found to reduce emissions more cost-effectively than CHP sized to meet the hot water load.

Solar PV and solar thermal are found to be two of the least cost-effective measures, although due to the assumed grant support, they are each more cost-effective than gas-fired CHP.

The cost-effectiveness of GSHPs varies significantly by scenario. They are an expensive way of reducing emissions in the KLO and BD scenarios, and a relatively cost-effective measure in the PD and SD scenarios. This is due to both the lower carbon intensity of grid electricity in the latter scenarios, making them a more effective carbon reduction measure, and the significant grant support available for their installation.

Air source heat pumps are less cost effective in the SD and PD scenarios due to their lower efficiency. In the KLO and BD scenarios, due to the lower assumed reductions in grid carbon intensity, their installation actually increases emission levels.

Biomass boilers are shown to be a relatively cost-effective measure. They compare favourably to gas-fired CHP, due to the greater carbon emission reductions achieved.

Results for NPV

The results for NPV only differ significantly from those for Peabody NPV if a measure affects resident fuel bills.

Fabric measures lead to reduced resident fuel costs, giving an NPV that is greater than the Peabody NPV in each case. This effect is most marked in scenarios with high fuel prices (PD and BD), where fuel bill savings are greater. In one case — applying fabric measures in void dwellings in the PD scenario — the NPV is positive, indicating a financial case for investment.

Consideration of NPV increases the cost-effectiveness of solar thermal relative to solar PV due to the fuel bill savings it brings.

In contrast, heat pumps have a lower NPV than their Peabody NPV. This is due to a switch to electricity bringing increased fuel bills for residents.

Sensitivity analysis

Using the approaches to sensitivity analysis described in chapter four, the sensitivity of the conclusions on cost-effectiveness to changes in model variables was explored. Figure 5.1.1 illustrates the results for the KLO scenario, indicating the range of results achieved for each measure. These results are representative of the range of uncertainty attached to each measure in other scenarios.

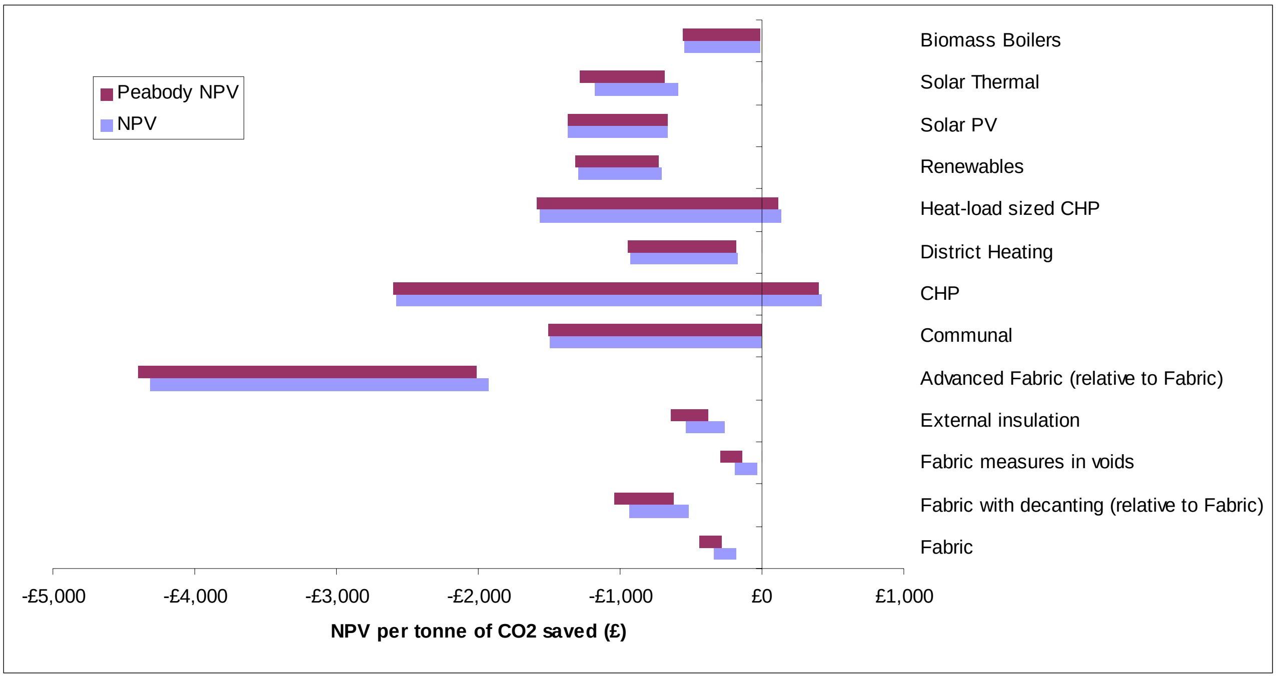

Figure 5.1.1 KLO scenario: range of values identified for NPV per tonne of CO_2 saved

The results show that there is significant uncertainty around the cost-effectiveness of CHP. This is due to the considerable range of possible capital costs assumed to be required for CHP installations. If CHP installation costs were at the low end of the range considered, then the measure could potentially have a positive NPV. Conversely, if costs were towards the high end of the range, the measure would be extremely costly relative to other carbon reduction measures.

Of the other measures considered, the Advanced Fabric approach also has significant uncertainty attached, but the conclusion that it is not cost-effective remains unaffected.

GSHPs do not feature in figure 5.1.1 as where carbon emissions associated with grid electricity are high, they do not lead to a reduction in emissions. The highest NPV achieved by GSHPs is -£1050, which is associated with the lower assumed limit in the carbon content of grid electricity. The same assumption leads to the only example of ASHPs reducing emissions in this scenario, with an NPV of -£2400.

For the remaining measures, the range of uncertainty is relatively low, and is insufficient in this scenario to lead to any other measure having a positive NPV. The broad preference for fabric improvements, biomass installations and district heating connections over solar PV and solar thermal appears to hold. However the uncertainty around costs demonstrates the importance of assessing the financial impacts of refurbishment on a case by case basis.

5.2. Alternative Model Assumptions

In this section, the impact of changing a number of assumptions and constraints used in the model is explored.

5.2.1. Solid wall insulation

The scenarios modelled make the conservative assumption that solid walls are not insulated externally on listed estates or estates in conservation areas, due to concerns about maintaining the appearance of architecturally-significant buildings.

Furthermore, internal insulation (for solid walls and floors) is only installed in void properties[3] as they become available so as to avoid the extra costs and disruption involved with

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[3] “void” properties are empty, recently vacated dwellings

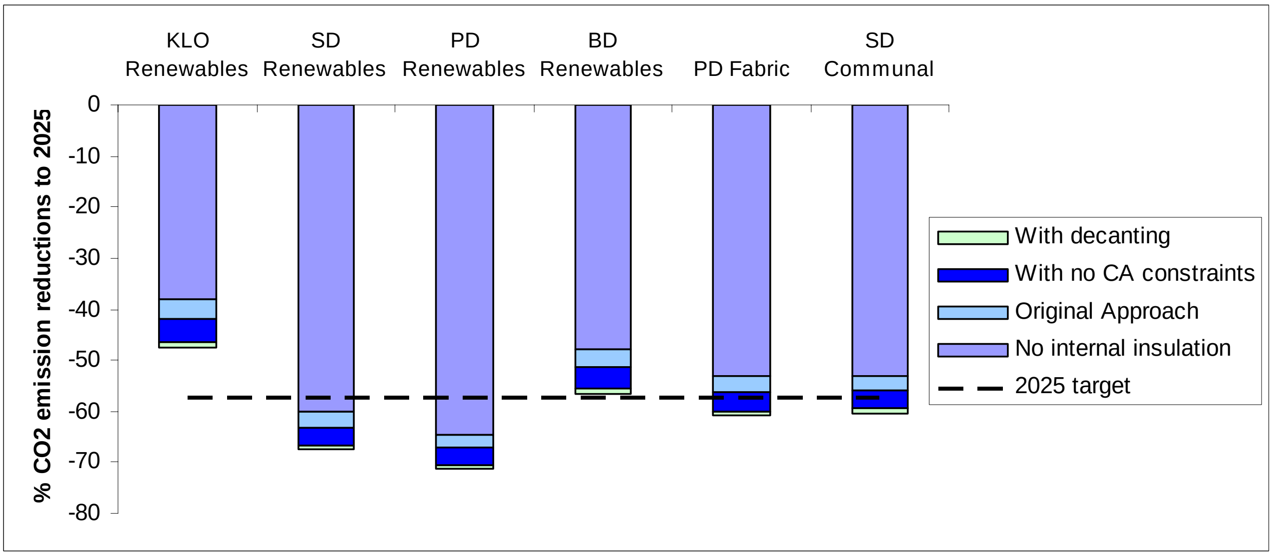

Figure 5.2.1 Impact of changing approach to solid wall insulation on carbon emissions

decanting[4] residents from their homes. The assumption based upon Peabody data that there is a change of tenancy in 4% of homes each year implies that only 54% of solid-walled homes in conservation areas receive internal insulation during the period 2011 to 2030.

The impact of three possible changes of assumptions regarding the Fabric approach are explored here: assuming that internal insulation is not installed in void dwellings at all; assuming that decanting is possible (so that whole estates can be decanted and then refurbished using internal wall insulation); assuming that there are no conservation area constraints, so estates in conservation areas (but not listed estates) can be externally insulated.

Results for carbon emissions

Across all the scenarios and approaches used, the impact on emission reductions of changing the approach to insulation is very similar. The results are shown below for the Renewables approach in each scenario, and the only two other cases where changing approach affects the achievement of the 2025 target (figure 5.2.1).

If internal insulation is not installed in void properties, this leads to the emission reductions achieved by 2025 being reduced by approximately 3% in each case.

Assuming that either decanting is possible or that estates in conservation areas can be externally insulated has very similar impacts, as in both cases this results in the majority of solid-walled homes receiving installation.

Emission reductions are slightly greater where decanting is possible, as this change enables floor insulation to be installed, and for all estates to be insulated (homes on listed estates remain untreated where only the conservation area constraint is removed). The impact on emissions is to bring about reductions to 2025 of a further 4% if conservation area constraints are removed, and of around 5% if decanting is used.

For the Renewables approach, this does not have an impact on whether or not the 2025 target is met. The 2025 target can still be achieved without internal insulation in the SD and PD scenarios, whilst insulating all solid walls does not enable the target to be achieved in KLO and BD.

The two examples where these changes do affect whether the 2025 target is met are the Fabric approach in the PD scenario and the Communal approach in the SD scenario. These approaches both originally narrowly miss the 2025 target, but are able to meet it through either decanting of residents or relaxing of conservation area constraints.

This is significant because, as discussed in section 5.1 above, insulation appears to be a more cost-effective carbon reduction measure

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[4] “decanting” refers to moving residents to temporary accommodation whilst improvements are carried out

than renewables and CHP in each scenario. This implies that the most cost-effective method of meeting the 2025 target in each scenario is likely to involve more extensive solid wall insulation, rather than being the Communal or Renewables approaches as originally defined.

Results for NPV

The results for NPV illustrate the differing cost effectiveness of insulation approaches between scenarios (figure 5.2.2.). For the KLO and SD scenarios, which are defined by relatively low fuel prices, NPV decreases as more homes receive insulation. Decanting residents to install internal insulation is shown to be a more costly option than applying external insulation on estates in conservation areas.

For the PD and BD scenarios, if internal insulation is not applied in void dwellings as they become available, this leads to little change in NPV. This indicates that the measure is broadly cost-neutral overall, as discussed in section 5.1 above.

The reduction in NPV where residents are decanted varies significantly between scenarios, and is least in the PD scenario due to high levels of grant support. It follows that a more cost-effective approach to meeting the 2025 target in the PD scenario is through a Fabric approach involving decanting of residents, rather than through the Renewables approach.

Results for fuel costs

The impact of changed insulation approaches on residents' fuel costs was assessed for Peabody stock as a whole and for residents on affected estates. A high fuel cost scenario (PD) and a low fuel cost scenario (KLO) were used to illustrate the impacts on both average rents and fuel poverty levels in 2030 (table 5.2).

Changing the approach used does significantly impact fuel costs, with insulation bringing slightly greater benefits in the high fuel price scenario. Installing insulation in void dwellings is shown to reduce average fuel costs by approximately £70 on conservation area estates. As only 54% of void dwellings are treated on these estates by that date, the actual benefit for treated homes is likely to be approximately double that figure. This would lead to average costs at similar levels to those that result from decanting residents to insulate homes.

Average costs are slightly lower where decanting is used in comparison to where estates in conservation areas are externally insulated, due to floor insulation also being applied.

Fuel poverty levels are reduced by 2% for treated conservation area homes in the PD scenario and 1% in the KLO scenario. The impact on overall Peabody fuel poverty levels is lower, as conservation area estates make up less than half of Peabody stock (approximately 44%).

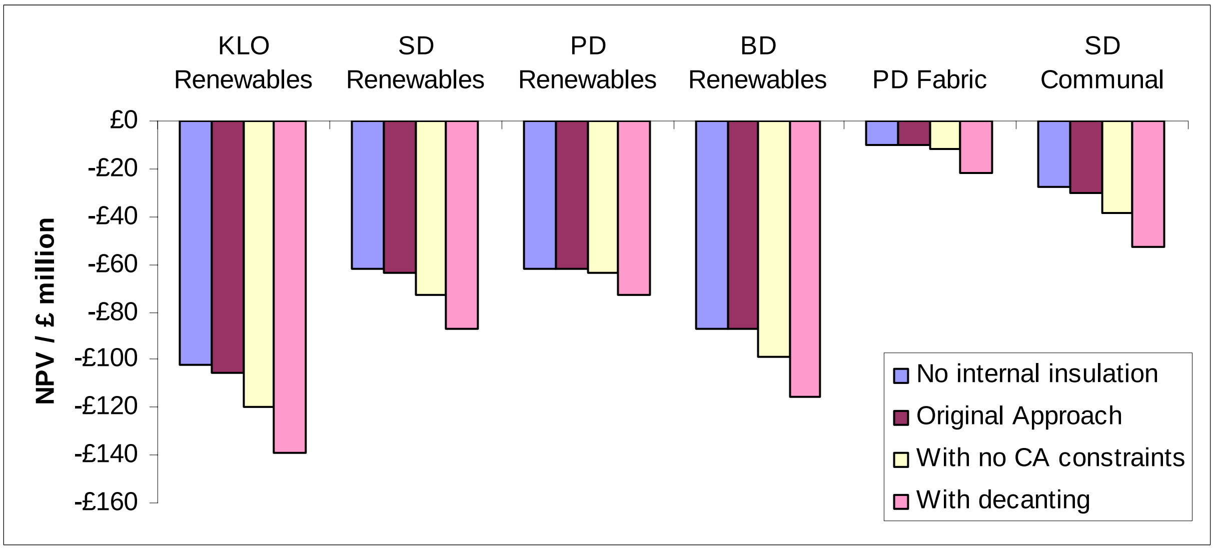

Figure 5.2.2 Impact of changing approach to solid wall insulation on NPV

Scenario and Package	2030 Resident Fuel Costs	2030 fuel costs with no internal insulation / £	2030 fuel costs with no Conservation Area Constraints / £	2030 fuel Costs with decanting / £
KLO Fabric – all estates	£775 (5% FP)	£805 (6% FP)	£752 (4% FP)	£747 (4% FP)
KLO Fabric – CA estates	£777 (6% FP)	£842 (7% FP)	£728 (4% FP)	£715 (4% FP)
PD Fabric – all estates	£752 (4% FP)	£783 (5% FP)	£727 (4% FP)	£721 (4% FP)
PD Fabric – CA estates	£759 (5% FP)	£827 (7% FP)	£706 (4% FP)	£692 (3% FP)

Table 5.2 Impact of changing insulation approach on resident fuel costs and fuel poverty

5.2.2. The advanced fabric approach

The Advanced Fabric approach assumes that the method of Passivhaus Refurbishment (Energie Institut 2007) is applied to the Peabody stock, to achieve the highest possible levels of insulation and airtightness, therefore minimising space heating requirements.

As decanting of residents would be a necessary part of this approach (for units where floor insulation and/or internal wall insulation is required), it has been contrasted to a Fabric approach that uses decanting for each scenario, and to the Fabric approach with the original set of assumptions.

Results for carbon emissions

The impact on carbon emissions is relatively low, with further reductions in the range 1-2% beyond those achieved by decanting residents to install internal insulation (figure 5.2.3). This leads to further reductions beyond the Fabric approach of 5.5% to 7.5%

The impact is greater in the KLO and BD scenarios where demand for space heating is higher. The error bars in figure 5.2.3 indicate the uncertainty around the result using the assumptions used for sensitivity analysis. Whilst this uncertainty is significant relative to the magnitude of emission reductions, it only increases or decreases the emission reductions achieved by around 1%.

Results for NPV

The impact on Peabody NPV of this approach is substantial for every scenario, leading to a value ranging from -£170 million to -£240 million (figure 5.2.4). There is significant uncertainty on the costs of this approach, as it has so rarely been applied to existing housing, but even with a low estimate of costs, it increases NPV for Peabody by £70-90 million relative to the Fabric approach with decanting.

The impact on NPV for Peabody and its residents considered together is similar and equally prohibitive.

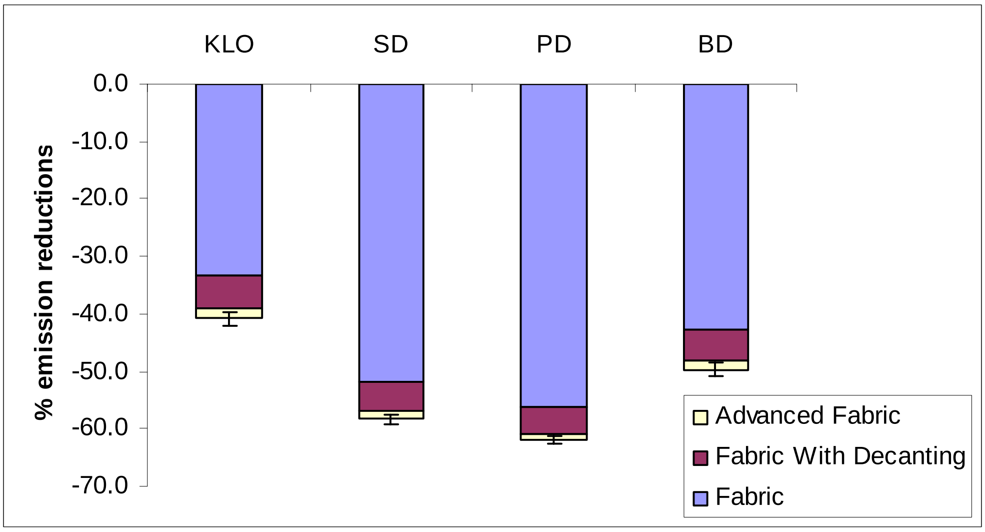

Figure 5.2.3 Impact of advanced fabric approach on carbon emissions

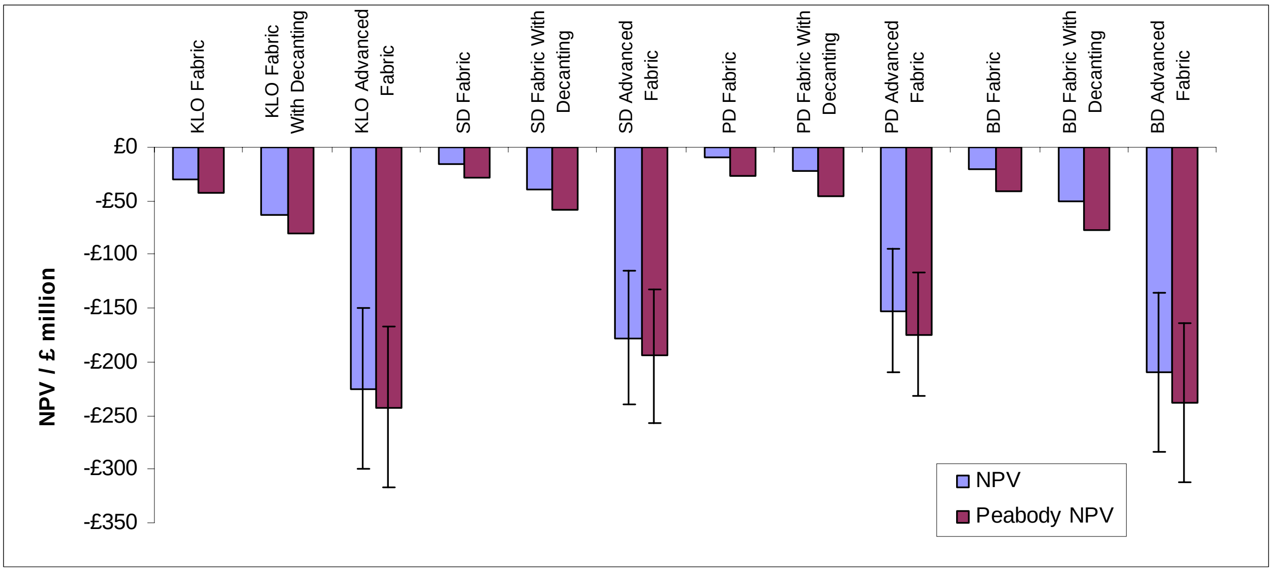

Figure 5.2.4 Impact of advanced fabric approach on NPV

	% residents in fuel poverty 2030: Fabric with decanting	% residents in fuel poverty in 2030: Advanced Fabric	Average 2030 resident fuel costs: Fabric with decanting	Average 2030 resident fuel costs: Advanced Fabric
Keeping the Lights On	4%	4%	£747	£745
Sustainable Development	2%	2%	£674	£685
Power Down	4%	4%	£721	£739
Breaking Down	9%	8%	£912	£911

Table 5.3 Impact of Advanced Fabric measures on fuel costs

Results for fuel costs

The results for resident fuel costs indicate that using the Advanced Fabric approach in preference to the Fabric approach with decanting brings no significant reductions in fuel costs or fuel poverty for residents (table 5.4).

Indeed in the PD and SD scenarios, where the increase in electricity prices is high relative to gas prices, the increased spending on electricity to power mechanical ventilation with heat recovery units over-rides the savings in space heating costs leading to a net increase in average fuel costs.

5.2.3. Installing heat pumps

In the original Renewables approach considered in this research, heat pumps are not considered due to the likely increase they would bring in resident fuel costs, and doubts about whether they would bring reductions in emissions in each scenario.

Nevertheless, both ground source heat pumps (GSHPs) and air source heat pumps (ASHPs) could play a significant role in reducing emissions in Peabody stock, especially if significant decarbonisation of the grid is achieved. The implications of installing both GSHPs and ASHPs are explored in this section.

It is assumed that GSHPs can be installed in any Peabody houses or bungalows with gardens, with a borehole being used to house the heat pump pipework. The potential for GSHPs assumed for this research will represent an upper limit on what is viable in practice, as many dwellings will not be suitable due to gardens being too small or inaccessible for digging equipment, or due to the ground on a particular site not being suitable for a borehole.
ASHPs are installed in flats on estates that are not listed or in conservation areas (due to the visual impact of the units) and where average floor areas are below 60m^2 (WWF 2008).

It is assumed that heat pumps are used with over-sized radiators, due to the expense and disruption involved in installing underfloor heating, which would be a more efficient option.

To avoid competition with communal infrastructure, they are not installed on estates receiving a district heating connection. They are used to provide both space heating and hot water, so are used in preference to solar thermal where that option is available.

Results for carbon emissions

GSHPs lead to an overall reduction in emissions of around 1% for SD and PD, and of 0.7% for KLO and BD (table 5.4). Conversely, the less-efficient ASHPs lead to further reductions of 0.4% for PD and SD, and increase emissions for KLO and BD by 0.3%. This is due to the need for low-carbon grid electricity for heat pumps to reduce emissions relative to gas boilers.

Considering the impact on just those estates receiving the measure (table 5.5), the emission reductions for GSHPs range from 2% for KLO and BD up to around 6% for PD and SD. ASHPs are a successful measure for PD and SD, bringing reductions of nearly 4%, whilst emissions are increased by over 3% in the remaining two scenarios.

Scenario	Renewables	Renewables with GSHPs	Renewables with GSHPs and ASHPs
Keeping the Lights On	-42.0	-42.7	-42.3
Sustainable Development	-63.2	-65.4	-65.8
Power Down	-67.2	-69.2	-69.6
Breaking Down	-51.4	-52.1	-51.7

Table 5.4 Impact of heat pump installations on carbon emissions

Scenario	Renewables: potential GSHP estates	Renewables with GSHPs: treated GSHP estates	Renewables: potential ASHP estates	Renewables with ASHPs: treated ASHP estates
Keeping the Lights On	-38.0%	-40.1%	-37.2%	-33.5%
Sustainable Development	-57.9%	-64.3%	-63.0%	-66.7%
Power Down	-62.7%	-68.5%	-67.6%	-71.0%
Breaking Down	-48.3%	-50.1%	-48.6%	-45.2%

Table 5.5 Impact of heat pump installations on carbon emissions for treated estates

Results for NPV

The impact on NPV is not favourable in any of the scenarios, for both GSHPs and ASHPs (figure 5.2.5). NPV is reduced in each scenario where GSHPs are installed, although the impact varies significantly, from -£3 million to -£15 million. This is due to the different levels of grant support offered between scenarios. The same is the case for ASHPs, with reductions in NPV from -£2 million to -£8 million.

The reductions in Peabody NPV are less than the reductions in NPV, indicating that residents are worse off financially after heat pump installations, both for GSHPs and ASHPs.

Results for fuel costs

For each scenario except BD, fuel costs for residents are increased when heat pumps are installed, both for GSHPs and ASHPs (table 5.6). This is due to the switch from a cheaper fuel in the form of gas, to a more expensive fuel in the form of electricity, despite the efficiency saving that heap pumps provide.

The increased fuel costs result in fuel poverty levels increasing. For KLO and SD there is a 2% increase, taking fuel poverty levels up to 7% and 5% respectively. The impact is strongest in the BD scenario, where fuel poverty levels increase by 6% up to 19%.

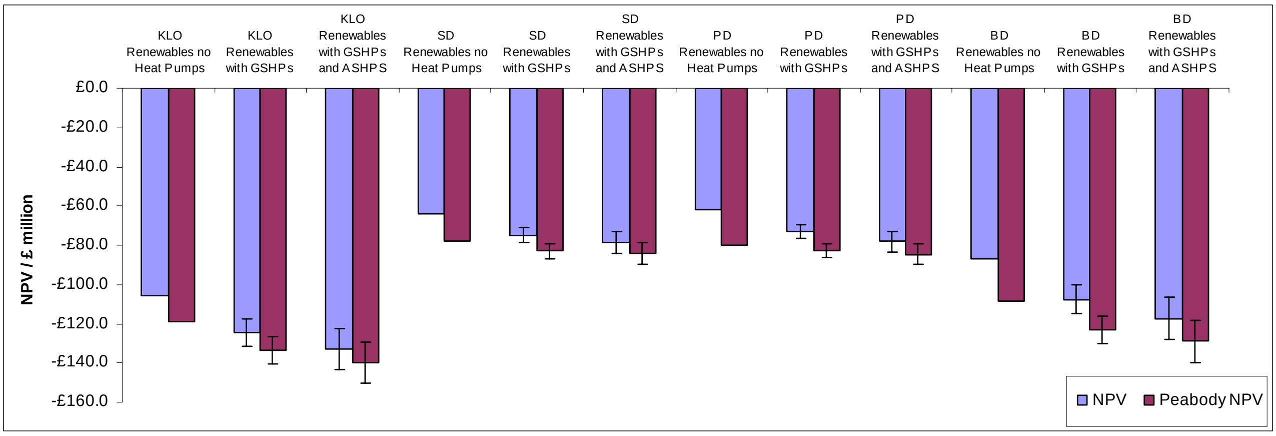

Figure 5.2.5 Impact of heat pump installations on NPV

Scenario	Renewables	Renewables with GSHPs	Renewables with GSHPs and ASHPs
Keeping the Lights On	£686	£701	£710
Sustainable Development	£658	£679	£689
Power Down	£691	£716	£727
Breaking Down	£785	£804	£816

Table 5.6 Impact of heat pump installations on average 2030 fuel costs

5.2.4. Financial incentives for micro-generation

The Peabody Energy Model allows several different options to be chosen that affect the financial rewards for the generation of electricity and heat onsite:

- Electricity generated by either solar PV or CHP can be either sold to residents or entirely exported to the grid.
- Two types of government incentives for renewable electricity generation can be considered — the current Renewables Obligation (RO) approach, through which at present Peabody receive around £41 per MWh of electricity generated, or a feed-in tariff (FIT) approach, through which electricity exported to the grid receives a guaranteed price that exceeds the grid price for electricity (although the price available for new installations declines year by year).
- A Renewable Heat Obligation (RHO) is considered, as recently proposed by the UK government (BERR 2008), which rewards generation of renewable heat (through solar thermal or biomass boilers) by paying 2p per unit of heat generated.

Since the modelling work was carried out for this research, FITs have been endorsed by the UK government, and can be expected to apply to micro-generation (DECC 2008). However, the method of implementation and the value of FITs is yet to be decided, so the results of this research point towards the potential impact they could bring about.

All scenarios make the original assumption that electricity is sold to residents on estates where CHP is installed. This approach maximises income in the current context, as a low price is currently paid for exports of electricity to the grid. Where PV alone is installed, it is assumed that all electricity generated is exported to the grid. This is current practice for existing PV installations at Peabody, and is more lucrative than exporting electricity generated by CHP, due to the support available through the RO.

For estates with CHP, this approach has the organisational implication for Peabody that it is responsible for supplying energy to its residents where CHP is installed. It is therefore assumed that, as is current practice on the BedZED estate, an intermediary organisation is used to provide a billing and metering service. Furthermore, it is assumed that electricity meters and the internal distribution wiring on estates are purchased from the local electricity network operators. If it is assumed that electricity from CHP is sold to the grid, the latter costs are not incurred.

In this section, the implications of exporting all generated electricity to the grid and of changing the approach used to support on-site generation of heat and electricity are explored.

Results for Peabody NPV

The model results indicate that FITs provide an increased income for Peabody relative to ROCs, due to the relatively high price paid for generation of electricity (table 5.7). The impact is similar across scenarios, increasing Peabody NPV by approximately £6.9 million. A RHO also increases Peabody income, increasing NPV by approximately £500,000. Although this extra income is significant, it is not sufficient to change the conclusion that NPV for the Renewables approach is negative for each scenario.

	KLO	SD	PD	BD	Average
Peabody NPV increase due to FITs	£6,541,460	£6,674,090	£7,072,100	£7,231,985	£6,879,909
Peabody NPV increase due to RHO	£466,168	£465,043	£521,963	£548,516	£500,422

Table 5.7 Implications for Peabody NPV of support for energy onsite generation

For each scenario, NPV for Peabody is increased significantly if it sells electricity directly to residents rather than exporting it to the grid (figure 5.2.6).

The impact of this change ranges from around £5 million in the KLO and SD scenarios to £9 million for BD, with the difference being greatest in scenarios with high fuel prices.

Figure 5.2.6 Implications for Peabody NPV of exporting electricity to the grid

5.2.5. Communal heating approach

The Peabody Energy Model explores the implications of the conversion of existing individually heated estates to be fuelled by communal heating, either by district heating, gas-fired CHP, or biomass boilers.

For each of these approaches, there is little precedent so far in the UK. Indeed, no conversions of estates from individual gas heating systems to communal systems are known of in the UK to the author.

The cost-effectiveness of combined heat and power on the scale of the larger Peabody estates — typically comprising 100–250 dwellings — has also been questioned by several industry experts in discussions with Peabody over recent years.

There are few examples of biomass installations in central London, with the first installation of a large-scale biomass boiler reportedly taking place in 2007 (Econergy 2007). There are also doubts about whether sufficient suitable fuel could be sourced to make this approach feasible and sustainable. Concerns about impacts on air quality may also limit the application of biomass as a fuel in central London.

The picture is more positive for district heating, which has the strong support of the GLA, and for which connections to existing housing are currently underway in London, including on Peabody's Pimlico estate.

In the light of the uncertainties around developing new communal heating on Peabody estates — either through CHP or biomass boilers — this section explores the impact of installing either CHP, biomass boilers or no estate-level communal heating on the model results.

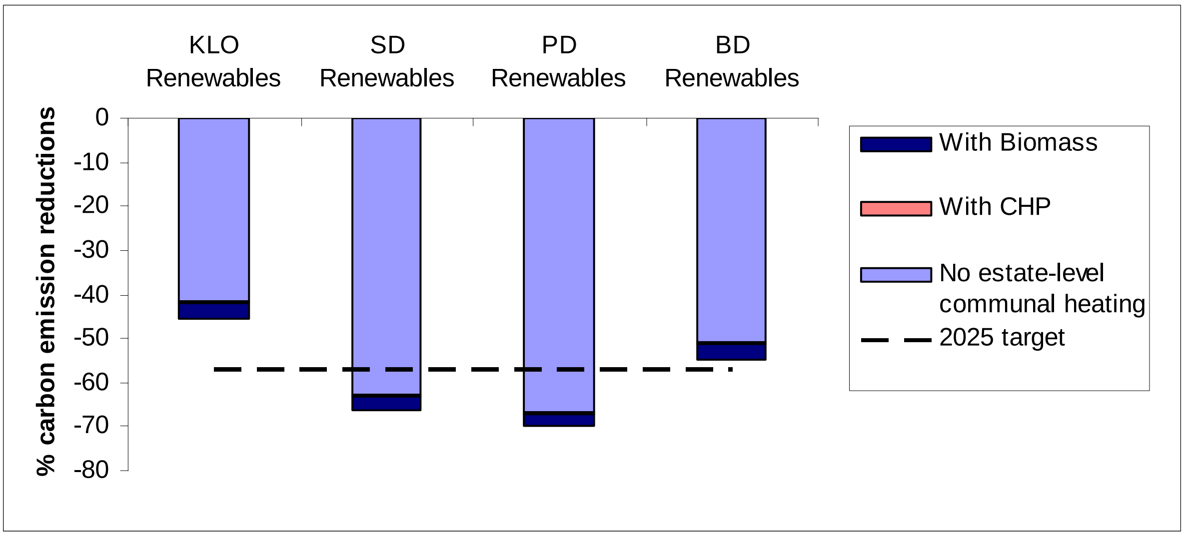

Figure 5.2.7 Impact on carbon emissions of approaches to communal heating

Results for carbon emissions

The impact on emissions of installing CHP on estates is very low. Emissions are reduced by approximately 0.5% in each scenario (figure 5.2.7). The low reductions are due to grid decarbonisation in each scenario, reducing the carbon savings associated with displacing grid electricity. This effect means that by 2029 in the PD and SD scenarios, installing CHP on an estate is a higher-emission option than continuing to use individual gas boilers.

Biomass boilers lead to greater emission reductions, decreasing emissions by 3% in each scenario.

Results for Peabody NPV

There is little difference between the Peabody NPV resulting from installing CHP or biomass boilers (figure 5.2.8), although both figures are subject to some uncertainty.

As discussed previously, both measures reduce NPV for Peabody overall, and as they have a negligible impact on resident fuel costs, have a similar impact on overall NPV.

As the discussion in section 5.1 highlighted, the greater emission reductions from biomass boilers make them a much more cost-effective carbon reduction measure.

It should also be noted that the NPV results for CHP are dependent on the method of selling CHP electricity. If this electricity was sold to the grid instead of being sold to residents as assumed, the NPV for Peabody would be decreased by between £5-9 million (depending on scenario, as discussed in 5.2.4).

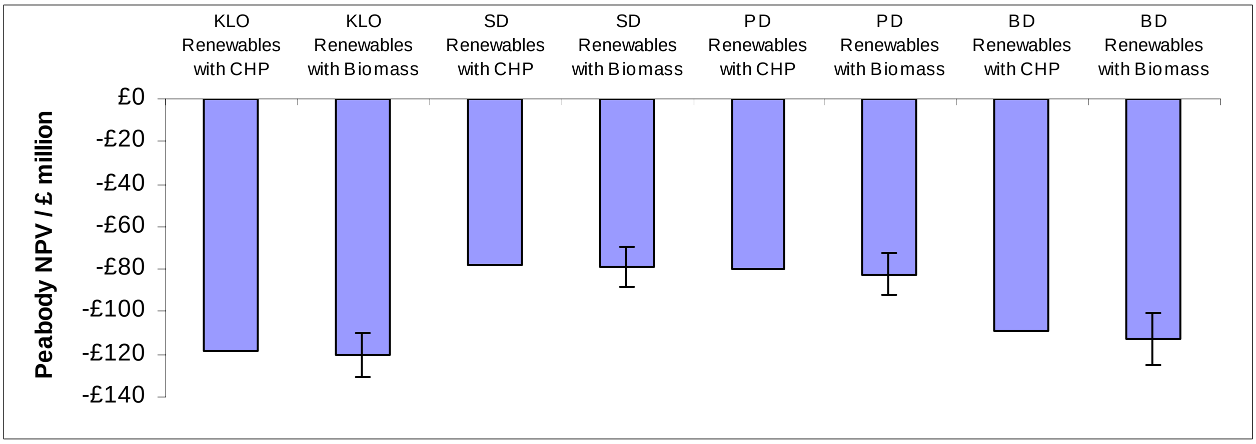

Figure 5.2.8 Impact on Peabody NPV of substituting biomass boilers for gas-fired CHP

5.2.6. Removing conservation area constraints for solar PV and solar thermal

The results given so far for the Renewables approach assume that no solar PV or solar thermal panels can be installed on listed estates or estates in conservation areas, so as to maintain the external appearance of these buildings.

This is a conservative assumption, as there are buildings now being refurbished in conservation areas where solar panels are permitted on roof space facing away from adjoining streets, and even some examples where they are fully visible to the public.

This section explores the implications of assuming that the constraints preventing installations of solar panels on estates in conservation areas are removed.

Listed estates form a small minority of Peabody stock, and it is assumed that their appearance can not be substantially altered, meaning that solar PV and solar thermal still can not be installed.

Results for carbon emissions

The results indicate that allowing solar PV and solar thermal installations in conservation areas leads to increased emission reductions of 4% in each scenario.

These further emission reductions greatly increase the confidence that the 2025 target is met for SD and PD and reveal potential to achieve emission cuts beyond 70% by 2025.

For the BD scenario, the modelled emission reductions are close to 57%, which, given the uncertainties in the model, indicates a chance that the 2025 target could be met.

Results for NPV

Further installations of solar PV and solar thermal have a significant impact on NPV for Peabody, leading to reductions of between £22 million and £36 million. The reductions in NPV are greatest in those scenarios where renewables receive the least grant funding support and do not benefit from FITs or declining installation costs.

Results for fuel costs

The overall impact on resident costs and fuel poverty is minor, with average costs being reduced by around £5 in all scenarios except BD where they are reduced by £8. This low impact is due to only solar thermal leading to reduced resident fuel bills, and the relatively low amount of solar thermal installations (only on houses and top floor flats).

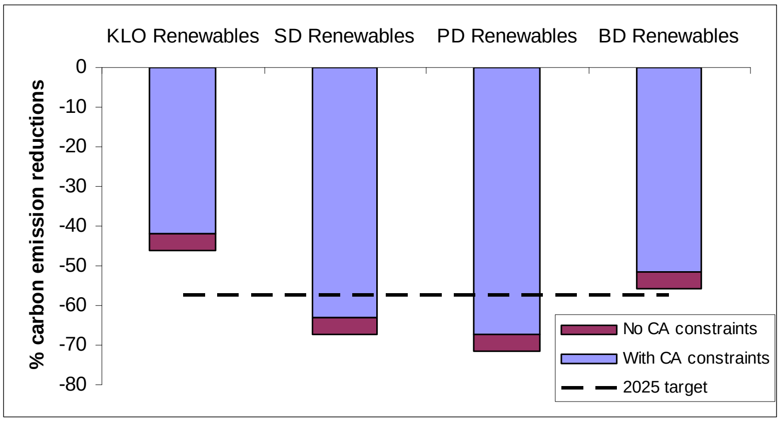

Figure 5.2.9 Impact of removing conservation area constraints for solar PV and solar thermal on emission reductions

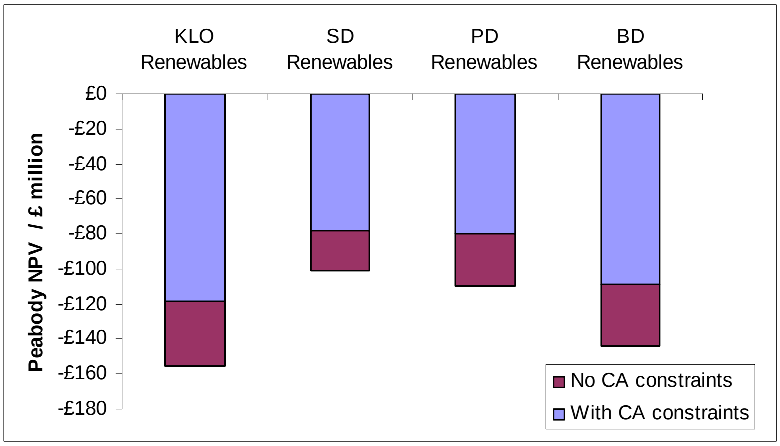

Figure 5.2.10 Impact of removing conservation area constraints for solar PV and solar thermal on NPV and Peabody costs

5.2.7. Shadow Price of Carbon

The financial assessment of stock refurbishment outlined so far does not take into account the benefits to society as a whole of reducing carbon emissions. This issue can be addressed by putting a financial value on each tonne of carbon dioxide saved. This was done for this research using Defra's shadow price of carbon (SPC). The SPC is a measure of the marginal damage caused by the emission of an extra tonne of CO_2 (Defra 2007a).

The government recommends the use of the figure of £25 per tonne of CO_2 in 2007, increasing by 2% a year in real terms. There is however some debate amongst academics and economists whether this is an appropriate figure to use, and figures ranging from $25 to $85 dollars per tonne of carbon (equating to a range of £23 to £77 per tonne of CO_2 in 2011) have been suggested.

The approach has also been criticised for not being useful for policy appraisal due to the circular nature of its definition — it is dependent upon the assumed global carbon emissions trajectory, but the level it is set at significantly affects this outcome (Friends of the Earth 2008).

Despite these limitations, the impact of the SPC on the NPV calculations has been assessed using the Government's definition, to identify the effect it has on the financial case for refurbishment. The high and low figures given above were used to generate upper and lower estimates of its impact. Applying the SPC figure has the effect of increasing NPV, as the annual carbon emissions savings for each year up to 2030 relative to the Base approach are multiplied by the SPC, to create a notional increase in income for that approach.

If consideration of the SPC leads to a positive NPV, this can be interpreted as evidence that there is a "long-term social case" for the refurbishment approach to be carried out (going beyond the "business case" that Peabody NPV explores, and the "social case" assessed by NPV). The results were assessed for both NPV and Peabody NPV, and in each case the level of SPC required to give a zero NPV was also calculated.

Results for NPV

Using the SPC has a relatively low impact on the majority of NPV results (figure 5.2.11). NPV is increased by up to £5 million for each case considered.

The order of preference of refurbishment options within scenarios is unaffected. NPV is also negative in every case, even where a high value for the SPC is considered (shown by error bars). The SPC required to give a zero NPV (table 5.8) is some way beyond the range of suggested values given above.

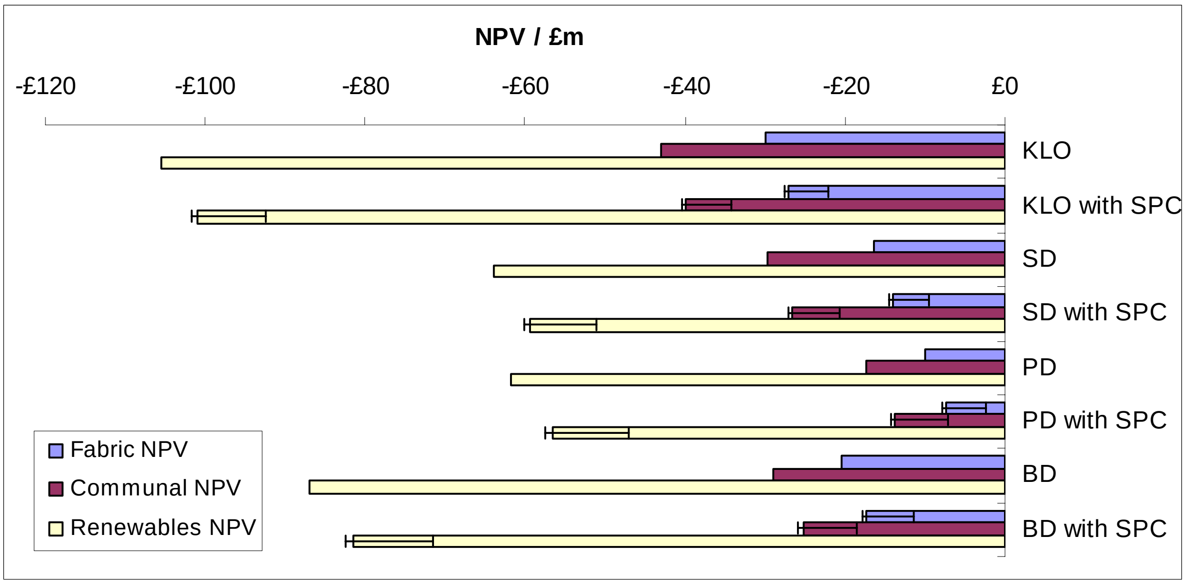

Figure 5.2.11 Impact of Shadow Price of Carbon on NPV

	KLO	SD	PD	BD
Fabric	£296	£181	£100	£174
Communal	£370	£253	£130	£213
Renewables	£624	£378	£320	£431

Table 5.8 SPC required (in 2011) to give zero NPV by approach and scenario

Results for Peabody NPV

Applying the SPC does not lead to a positive Peabody NPV for any approach or scenario considered (figure 5.2.12). Consideration of the SPC also makes no difference to the choice of ranking of refurbishment approaches by NPV for Peabody.

To achieve a zero NPV for Peabody, an SPC in the range £255 - £702 per tonne of CO_2 would be required (table 5.9), far beyond the range suggested to date by economists.

Discussion

These results could be taken as implying that emission reductions in housing through the considered refurbishment measures are simply too costly, and that the burden should be met in other sectors, where projects may be cost effective where SPC is considered.

This conclusion should be treated with caution though, given the common claim that housing may be one of the least challenging sectors of the economy in which to achieve emission reductions (Bows et al. 2006).

If that is the case, then it appears that use of the SPC within the range currently advocated by economists may not lead to decisions to invest in carbon reduction measures that are required to meet climate change targets. If that is the case, the criticisms made of the SPC by Friends of the Earth (2008) appear to have some validity.

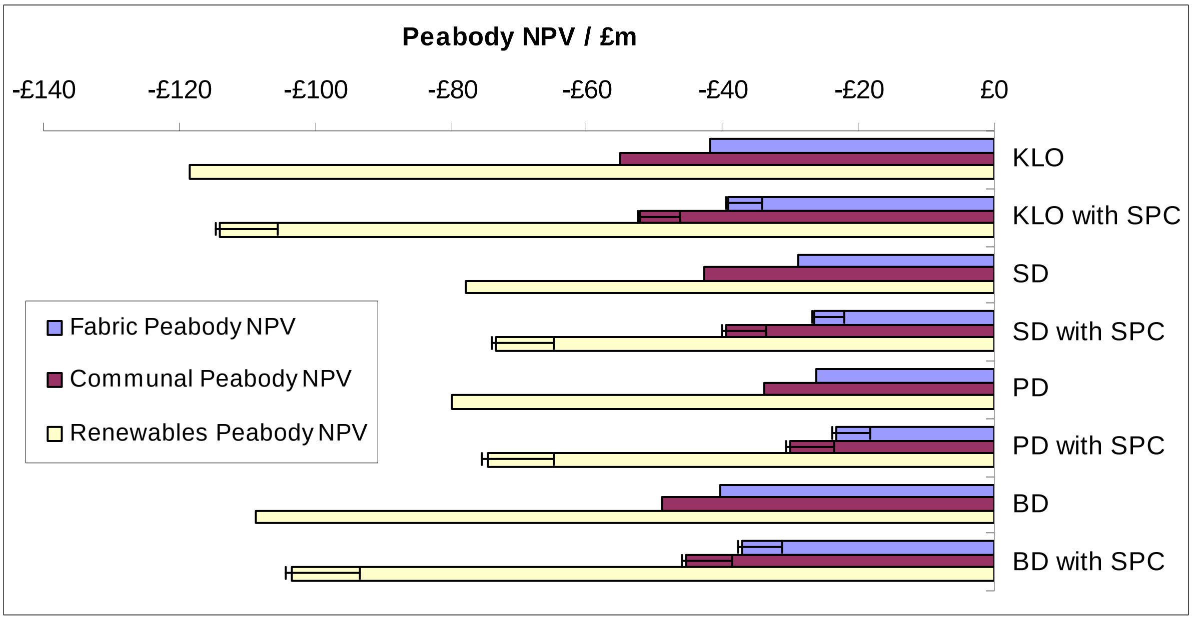

Figure 5.2.12 Impact of Shadow Price of Carbon on Peabody NPV

	KLO	SD	PD	BD
Fabric	£414	£319	£258	£341
Communal	£474	£361	£255	£361
Renewables	£702	£460	£413	£540

Table 5.9 SPC required (in 2011) to give zero Peabody NPV by approach and scenario

5.2.8. Reduced VAT rates for refurbishment

Reduced rates for VAT for housing refurbishment measures have been called for by a number of bodies, in particular to improve the financial case for retrofitting relative to demolition and rebuild (Sustainable Development Commission 2006; CLG Committee 2008). A number of the measures considered — insulation, solar PV, solar thermal and heat pumps — are already rated at 5% VAT (HM Revenue and Customs 2006). The impact of rating capital costs for all other measures at 5% on the cost-effectiveness of refurbishment was investigated.

Results

The impact on Peabody NPV of a reduced VAT rate is of the order of £1-4 million across the four scenarios, being greater in scenarios where less grant funding was available (table 5.10). This change makes little difference to the overall viability of funding refurbishment for Peabody, where NPV is significantly negative in each case.

	KLO	SD	PD	BD	Average
Fabric	£2,422,579	£1,660,430	£1,663,090	£2,541,389	£2,071,872
Communal	£4,153,758	£3,631,313	£3,168,999	£3,921,827	£3,718,974

Table 5.10 Reduction in Peabody NPV due to reduced VAT rate for refurbishment

5.2.9. Retaining electric storage heaters

It is assumed in each scenario modelled that on the small number of estates that are entirely (or in three cases, partially) heated by electric storage heaters, these heaters are replaced with individual gas boilers as part of the Fabric improvement package. This is done largely to reduce resident fuel costs, but also because at current levels of carbon intensity of the grid, gas boilers provide lower carbon heating. This section explores the impact of not carrying out these replacements on the model results.

Results for carbon emissions

The impact on overall emission reductions to 2025 of this change of approach is minor, but the impact on estates with electric heating is significant (table 5.11). For the whole stock, if storage heaters are replaced, emissions for the Fabric approach are reduced by a further 0.1% to 2025 in the SD and PD scenarios, and a further 0.6% in the KLO and BD scenarios. For electrically-heated estates, the reduction due to replacing storage heaters ranges from 5-6% in the SD and PD scenarios to 18-19% in the BD and KLO scenarios.

By 2030, assumed decarbonisation of the grid leads to electric heating being a lower carbon option for both the SD and PD scenarios. Emission reductions for the Renewables approach are 75% with electric heaters for PD (relative to 73% with gas boilers) and 71% with electric heaters for SD (relative to 68% with gas boilers).

Therefore the emission-related benefits of replacing storage heaters depend strongly on the future carbon emissions associated with grid electricity. If carbon grid intensity is to be reduced sharply, electric heating could be a lower-carbon option by 2030, potentially making it worthwhile in carbon terms to leave current electric heating systems in place.

	All estates: replaced	All estates: retained	Electric estates: replaced	Electric estates: retained
Keeping the Lights On	-33.3%	-32.7%	-46.8%	-27.5%
Sustainable Development	-51.9%	-51.8%	-63.5%	-57.5%
Power Down	-56.3%	-56.2%	-66.8%	-61.5%
Breaking Down	-42.9%	-42.3%	-54.6%	-37.1%

Table 5.11 Impact on carbon emissions of retaining electric storage heaters

Results for NPV

The impact on NPV of retaining storage heaters is to bring about an increase in NPV, ranging from £2.7 million to £3.9 million. Electric estates have a slightly negative NPV where heaters are retained due to two estates receiving insulation measures.

Results for Peabody NPV

Replacing storage heaters tends to decrease Peabody NPV by between £2 million and £3 million relative to the alternative of retaining them.

Results for fuel poverty

The impact on overall fuel poverty levels for Peabody stock is negligible, due to the very low numbers of electrically-heated estates.

For the estates themselves, fuel poverty levels are higher where storage heaters are retained. This effect is particularly marked for the SD and PD scenarios, where electricity prices increase at a greater rate than gas prices.

This situation creates a potential conflict between minimising resident fuel costs and minimising carbon emissions in the advent of substantial decarbonisation of the grid.

	All estates: replaced	All estates: retained	Electric estates: replaced	Electric estates: retained
Keeping the Lights On	-£29,904,781	-£27,401,143	-£2,637,302	-£133,664
Sustainable Development	-£16,477,531	-£14,281,038	-£2,324,580	-£128,087
Power Down	-£10,074,122	-£7,739,435	-£2,467,363	-£132,676
Breaking Down	-£20,485,562	-£17,740,543	-£2,900,389	-£155,370

Table 5.12 Impact on NPV of retaining storage heaters

	All estates: replaced	All estates: retained	Electric estates:	Electric estates:

			replaced	retained
Keeping the Lights On	-£41,835,065	-£38,921,809	-£3,010,148	-£96,892
Sustainable Development	-£28,974,973	-£26,188,041	-£2,870,000	-£83,068
Power Down	-£26,104,559	-£22,972,570	-£3,201,518	-£69,529
Breaking Down	-£40,293,987	-£36,907,004	-£3,473,032	-£86,048

Table 5.13 Impact on Peabody NPV of retaining storage heaters

	All estates: replaced	All estates: retained	Electric estates: replaced	Electric estates: retained
Keeping the Lights On	5%	5%	6%	11%
Sustainable Development	3%	3%	4%	15%
Power Down	4%	4%	6%	24%
Breaking Down	13%	13%	16%	32%

Table 5.14 Impact on fuel poverty of retaining storage heaters

5.2.10. Approach to solar installations

The impacts of installing solar PV and solar thermal on Peabody estates were investigated through this research, with the two measures together making up the Renewables approach. The original approach gives precedence to solar thermal, as this is the most efficient of the two technologies at turning solar energy into useful energy in the home. Solar PV is installed on all remaining available roof space except on north facing roofs. The effects of not installing either solar PV or solar thermal, or installing PV to a lesser degree are explored here.

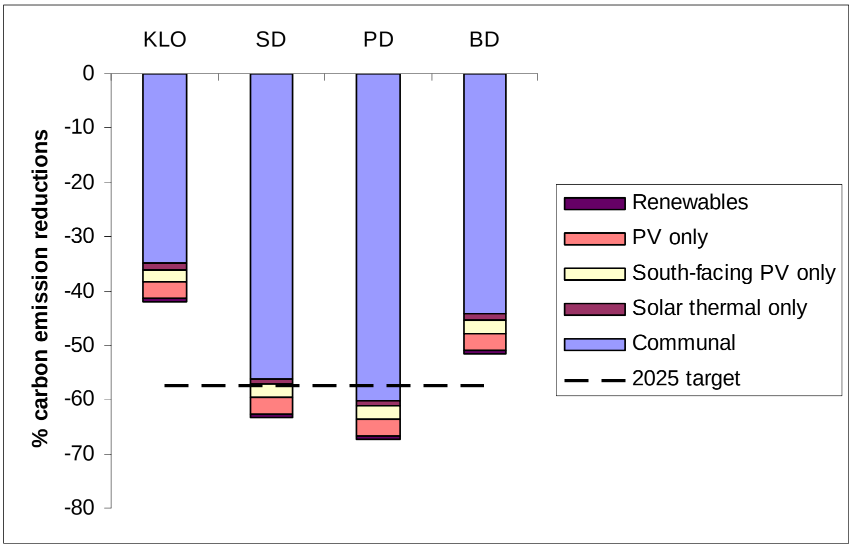

Figure 5.2.13 Impact of approach to solar panels on carbon emissions

Results for carbon emissions

The results show that the majority of the reductions through the Renewables approach come from solar PV installations. However, the Renewables approach, which combines PV and solar thermal, achieves greater reductions than if PV is used alone, which indicates that where solar thermal displaces PV on roof space, it leads to greater emission reductions.

If PV and solar thermal are each used to the maximum possible extent, overall emission reductions are increased by 7% in each scenario.

Results for Peabody NPV

NPV for Peabody is significantly reduced by solar PV and solar thermal installations. Costs for both solar PV and solar thermal are some way lower in the SD scenario where the highest levels of grant funding and feed-in tariffs are available. Nevertheless, neither measure has a positive NPV, even with this support.

Average resident fuel costs and fuel poverty levels are largely unaffected by the approach taken to renewables, as only solar thermal provides a fuel cost reduction, and only to a small number of residents. Average fuel cost figures in 2030 are reduced by between £7 and £12 depending on the scenario considered.

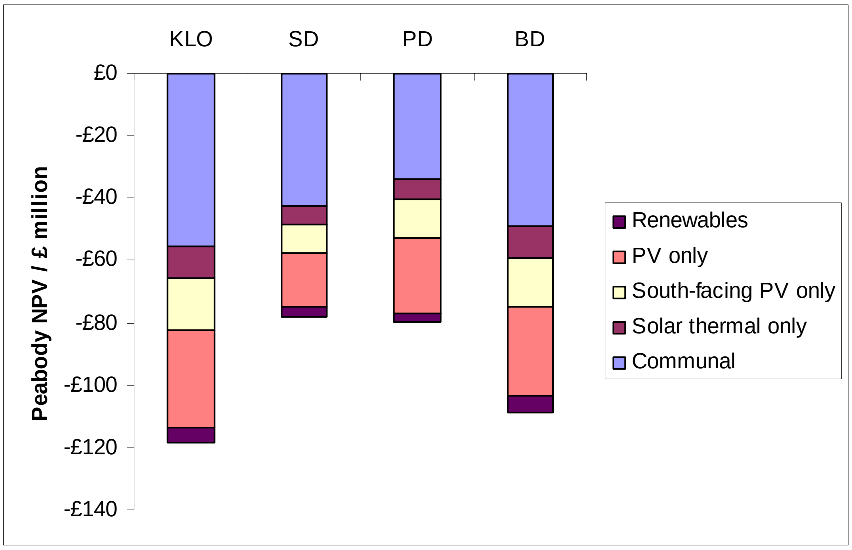

Figure 5.2.14 Impact of approach to solar panels on Peabody NPV

5.2.11. Fuel poverty reduction interventions

The UK Government has a statutory commitment to eliminate fuel poverty by 2016, and to eradicate fuel poverty in vulnerable households (including all social housing) by 2010. In the light of recent fuel price increases, it seems unlikely that the 2010 target will be met, whilst the 2016 target appears to be highly challenging.

In this section the impact of carrying out a rapid programme of fabric improvements to Peabody stock is assessed, such that all improvements are carried out by 2016. It is assumed that all solid-walled dwellings receive insulation, with residents on estates in conservation areas being decanted so that their homes can be internally insulated.

In addition, the cost-effectiveness of measures considered to reduce fuel poverty is assessed.

Results for fuel poverty

Rapid fabric improvements lead to fuel poverty being virtually eliminated on Peabody estates by 2016 for all scenarios except BD (figure 5.2.15). Fuel poverty levels in these scenarios are 0.6% or below, contrasting to a range of 1.9% to 4.2% achieved through the original Fabric approach.

The assumed rising fuel prices in each scenario lead to fuel poverty levels increasing again from 2016. If fuel prices were to instead remain steady from 2016, this would leave fuel poverty levels close to zero on Peabody estates for each scenario except BD. If fuel prices increase to a much greater extent, as is the case for BD, eliminating fuel poverty using insulation measures is unlikely to be feasible, although its extent can be reduced greatly.

Results for carbon emissions

A programme of rapid fabric improvements leads to a significant increase in the carbon emission reductions achieved by 2016.

The reductions achieved to 2025 are the same as those achieved through a programme of decanting residents to insulate homes by that date. However, the more rapid emission reductions lead to total emissions being significantly reduced over the assessment period, making more rapid emission reductions a stronger approach from a climate change mitigation perspective.

	2016			2025		
	Base	Fabric	Rapid fabric	Base	Fabric	Rapid fabric
KLO	-16%	-24%	-37%	-19%	-33%	-39%
SD	-28%	-36%	-46%	-40%	-52%	-57%
PD	-28%	-37%	-46%	-46%	-56%	-61%
BD	-16%	-24%	-37%	-30%	-43%	-48%

Table 5.15 Emission reductions achieved after rapid fabric improvements

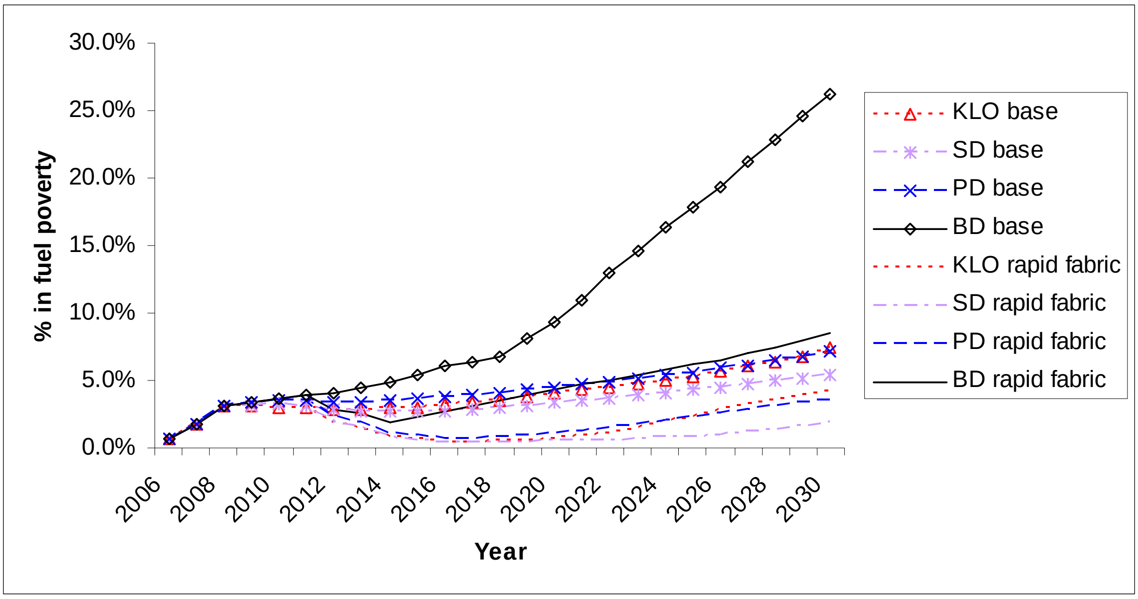

Figure 5.2.15 Impact of rapid fabric improvements on fuel poverty

	NPV (£million)			Peabody NPV (£million)		
	Fabric	Fabric with decanting	Rapid fabric	Fabric	Fabric with decanting	Rapid fabric
KLO	-£30	-£63	-£81	-£42	-£80	-£103
SD	-£16	-£40	-£49	-£29	-£58	-£70
PD	-£10	-£22	-£27	-£26	-£46	-£53
BD	-£20	-£50	-£63	-£40	-£78	-£97

Table 5.16 Impact of rapid fabric improvements on NPV

Results for NPV

Due to the front-loading of expenditure on stock improvements, a rapid programme of fabric improvements significantly decreases both NPV and Peabody NPV, and is therefore more challenging for Peabody to fund. The decrease in NPV is less than that for Peabody NPV in each case due to the extra savings in fuel bills achieved for residents.

Cost-effectiveness of fuel poverty reduction measures

The cost-effectiveness of measures that reduce fuel poverty on Peabody estates was assessed by calculating the change in NPV for Peabody for each £1 saving in resident expenditure on fuel (discounted to 2011 prices) over the period 2011 to 2030. The same discount rate that was applied to Peabody expenditure was also applied to resident expenditure on fuel in each scenario, to take into account a preference for achieving savings nearer to the present day.

An overall NPV of zero would equate to a £1 reduction in Peabody NPV to bring about a £1 saving for residents. As a result, a Peabody

NPV of less than -£1 indicates that Peabody expenditure exceeds resident savings.

Only those measures which lead to fuel bill savings for residents were considered. As a result, communal heating installations and solar PV were excluded from the analysis.

The results show that with one exception, each approach to fuel poverty reduction requires expenditure that exceeds the savings for residents (figure 5.2.16). The only exception to this is installing insulation in voids, which has an overall NPV close to zero in the PD and SD scenarios.

Both the replacement of electric heating and solar thermal are shown to require many times more spending than they save for residents in reduced bills.

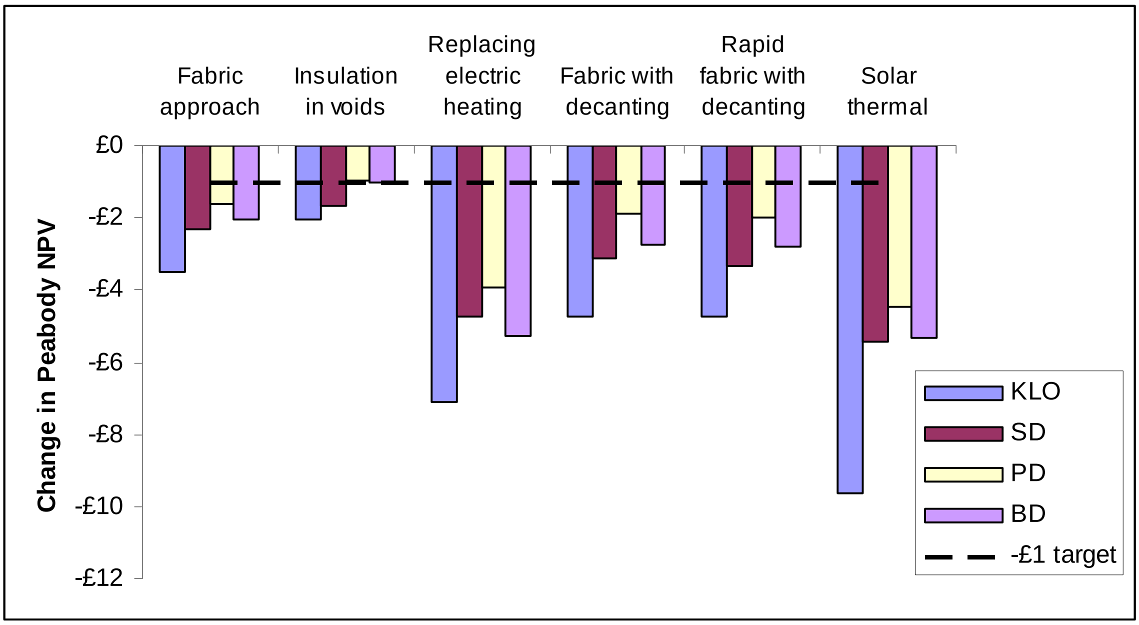

Figure 5.2.16 Change in Peabody NPV per £1 reduction in discounted resident spending on fuel

The measures considered are more cost-effective in scenarios where they are supported by grant funding (SD and PD) and in scenarios with low discount rates (PD and BD). Discount rates have an impact as higher rates put a reduced focus on cash flows that take place further into the future. As fuel poverty interventions involve upfront expenditure followed by year-on-year savings, higher discount rates therefore reduce the case for fuel-poverty interventions.

Based upon these results, from a fuel poverty perspective, it would appear to be more cost-effective for Peabody to simply reduce rents for fuel poor households rather than refurbish their homes. This is perhaps a surprising conclusion and contrasts sharply with the strong financial case for low-cost refurbishment measures such as cavity wall insulation or draught-proofing.

The idea of reducing rents for fuel poor residents could perhaps be practically administered on Peabody estates. If residents on electrically heated estates, or estates with uninsulated solid walls were given a rent discount as compensation for their relatively expensive heating systems, the results indicate that this could be a cheaper way of reducing their bills than replacing heating systems. However, the practical viability of such an approach is not clear, both in terms of its acceptability for landlords such as Peabody and its fit with legislation on rent levels.

Whilst the measures considered in this section may not be worthwhile purely from a fuel poverty perspective, they may still be deemed necessary from a carbon reduction perspective. If this is the case, any fuel bill reductions that result could still greatly benefit any residents in fuel poverty, and the existence of these savings is a further argument in their favour.

5.2.12. Summary

In this chapter, a number of changes to assumptions used in this research have been considered, along with the cost-effectiveness of carbon reduction measures.

The analysis of cost-effectiveness identified the change in both overall NPV and Peabody NPV for each tonne of CO_2 emissions saved by each measure. The results revealed that no measures have a positive overall NPV, with the exception of internal insulation in void dwellings in the Power Down scenario. Of the remaining measures, the Fabric approach, biomass boilers and district heating were the most cost-effective at reducing emissions. CHP was also a relatively costly carbon reduction measure, although there is significant uncertainty about this conclusion.

Solar PV and solar thermal were each very costly, although they could be made much more cost-effective by grant support. Ground source heat pumps were extremely costly in the BD and KLO scenarios, but relatively cost effective in the PD and SD scenarios where grid carbon intensity was lower and they received more grant support. Air source heat pumps were less cost-effective than ground source heat pumps, and in scenarios defined by weak decarbonisation of the grid, do not decrease emissions at all.

Installing insulation in void dwellings as they become available was shown to be a relatively cost-effective measure that effectively reduces emissions and resident fuel bills. Decanting residents to install internal insulation was shown to be more cost effective and to benefit residents more financially than installing CHP, solar PV or solar thermal. Through a fabric-only approach to refurbishment that uses decanting, the 2025 target could be met in the Power Down and Sustainable Development scenarios without CHP or renewables, and at a lower cost.

The Advanced Fabric approach, which represents the maximum effort that Peabody can undertake to reduce demand for space heating in its stock, was found to be extremely expensive relative to other carbon reduction measures. This is due to diminishing returns that are realised when applying additional insulation measures to well-insulated homes.

The option of installing ground source or air source heat pumps was considered, and it was found that they only achieve significant emission reductions and reasonable cost-effectiveness when installed in scenarios defined by low carbon grid intensity. Their installation leads to increased fuel costs for residents, indicating a potential conflict between carbon emission reduction and fuel poverty reduction if they are used by Peabody.

Where the financial incentives for micro-generation were explored, it was found that feed-in tariffs benefit Peabody more than the current Renewables Obligation system, and that CHP is more cost-effective if electricity generated is sold to residents.

The greatest impact from communal heating was found to come from district heating connections. CHP has a relatively low impact on emission levels and becomes a more carbon-intensive technology than combining individual gas boilers with grid electricity by 2030 in the PD and SD scenarios. Biomass boilers are found to bring about much greater emission reductions than CHP, though their use is in central London may be constrained by concerns about air pollution.

If the installation of solar panels is permitted on Peabody's estates in conservation areas, further emission reductions of up to 4% are achieved, but these come at a significant cost.

The impact of attributing a value to emission reductions was explored using Defra's Shadow Price of Carbon. It was found that both NPV and Peabody NPV are still negative for every approach in every scenario where it is considered. It therefore does not create a case for refurbishment beyond Peabody's current planned approach.

Assuming the availability of reduced VAT rates for refurbishment has little impact on results, reducing NPV for Peabody by up to £4 million. The option of retaining electric storage heaters rather than replacing them with gas boilers is assessed and is found to be beneficial in terms of NPV but slightly detrimental in terms of carbon emissions. However electric heating does bring about lower carbon emissions by 2030 in the SD and PD scenarios, so from a carbon reduction perspective, there is potentially a case for retaining it in Peabody homes if grid carbon intensity can be expected to fall significantly over coming years. This approach could however be problematic from a fuel poverty perspective.

Consideration of the approach to renewables reveals that most of the emission reductions achieved through this approach are through solar PV installations. However, per square metre of roof space covered, solar thermal has a greater impact in reducing emissions.

The impact of a rapid programme of fabric improvements was assessed, to assess the viability of eliminating fuel poverty by 2016 on Peabody estates. It was found that for all scenarios except Breaking Down, fuel poverty levels could be brought close to zero through this approach by 2016. However, the assumed increases in fuel prices in each scenario lead to fuel poverty increasing again up to 2030. If high fuel price levels are assumed, Peabody can not eliminate fuel poverty on its estates through fabric measures.

Finally, the cost-effectiveness of measures that reduce resident fuel bills was assessed, and it was found that in each case Peabody spending exceeds resident savings. This implies that the measures considered are best justified in terms of their carbon reduction potential, with any reductions in resident fuel bills that follow being an additional benefit.

6. APPROACHES TO MEET CO_2 REDUCTION TARGETS

In the light of the analysis above, the approaches available for Peabody to meet the GLA's carbon reduction target for 2025 are discussed. Approaches are considered in turn for the four modelled scenarios, followed by a broader discussion of possible strategies and possible methods to fund the improvements. The viability of achieving zero net carbon emissions on Peabody estates by 2030 is then assessed.

6.1. Meeting the GLA's target

6.1.1. Keeping the Lights On

As discussed in chapter three, the model results indicate that with the constraints assumed in the KLO scenario, the GLA's carbon reduction target can not be met. The key factors that affect this conclusion, as identified in chapter four, are the assumed values for carbon intensity of grid electricity and resident demand for energy.

Using the assumption that constraints external to Peabody cannot be changed, but allowing Peabody's own approach to be improved, the viability of meeting the 2025 target was explored.

If the constraint on decanting residents is removed, emissions reductions can be increased from 42% to 47.5% for the Renewables approach. If an Advanced Fabric package is applied, emissions reductions reach 49.4%. If Biomass boilers are installed instead of CHP this increases to 53.1%. This is the limit of reductions that can be achieved in the KLO scenario through Peabody's efforts alone.

The 2025 target of a 57.4% reduction in emissions is therefore not achieved. With a shortfall of more than 4%, this conclusion is likely to be robust, even where the uncertainties affecting model results discussed in chapter four are taken into account.

6.1.2. Sustainable Development

For this scenario, it was found that the 2025 target is met relatively comfortably for the Renewables approach, and was close to being achieved for the Communal approach. Based on the issues discussed in chapter five of this report, seven approaches are put forward to meet the 2025 target (table 6.1).

These approaches were also assessed for the cost-effectiveness with which they reduce emissions (table 6.2), using the same method as that used for individual measures in chapter five.

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
Rapid Good Confidence	Fabric with decanting by 2016; District Heating; Solar Thermal; Biomass boilers	65%	-£67 million	-£89 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 6.1 SD scenario: approaches to meet the GLA target

Approach	NPV per tonne of CO_2 saved	Peabody NPV per tonne of CO_2 saved

Biomass	-£183	-£261
Decanting	-£256	-£360
Solar PV	-£294	-£361
Renewables	-£321	-£391
Rapid Good Confidence	-£278	-£369
Good Confidence	-£262	-£350
Maximum	-£346	-£388

Table 6.2 SD scenario: cost-effectiveness of approaches to the meet the GLA target

The approach that is most cost-effective for Peabody is the Biomass approach, which comprises fabric improvements, biomass boiler installations and district heating connections. If biomass boilers can not be installed, decanting residents so that installation can be installed or installing solar PV has similar impacts in terms of costs-effectiveness for Peabody, although greater emission reductions are achievable through the latter.

The original Renewables approach achieves 63% reductions, and reductions of up to 73% are achievable by 2025 through a Maximum approach that applies all possible measures (except Advanced Fabric).

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 most cost-effective approach 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.

For the SD scenario, the Good Confidence approach is an extensive approach to refurbishment comprising fabric improvements with decanting, district heating, solar thermal and biomass boiler installations. As the most cost-effective measures are selected, it achieves greater emission reductions than the Renewables approach and with a greater NPV per tonne of CO_2 saved.

Taking into account the benefits of a rapid programme of fabric improvements identified in chapter five, a Rapid Good Confidence approach was also devised, which extends the Good Confidence approach by carrying out all fabric improvements by 2016. This approach has an NPV for Peabody of -£89 million.

Overall, the approaches identified have an NPV for Peabody of between -£43 million and -£111 million, indicating a significant funding gap no matter which approach is pursued.

6.1.3. 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, increased availability of low carbon energy and strong support for carbon reduction measures. As a result, a number of distinct approaches are available to Peabody to meet the 2025 target (table 6.3).

A number of different technologies if applied in addition to fabric improvements can increase emission reductions to between 58% and 63%. The District Heating, Biomass and Decanting approaches each perform strongly in terms of having the highest values for NPV per tonne of CO_2 saved.

If a good confidence of meeting the 2025 target is desired, the most cost-effective approach involves a combination of fabric improvements with decanting, district heating and biomass boilers. This is less extensive than for the SD scenario where solar thermal was also required.

This approach is significantly more cost-effective than approaches which achieve comparable levels of emission reductions, due to not relying on solar PV installations.

However, if deeper emission reductions are pursued, solar PV is likely to be required. The maximum reductions achievable by 2025 in this scenario are 76%, through an approach combining all reasonably cost effective measures. This approach has an NPV for Peabody of just over -£100 million.

The funding gap for this scenario is not quite as great as for SD, with NPV for Peabody ranging from -£35 million to -£103 million.

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
Rapid Good Confidence	Fabric with decanting by 2016; District Heating; Biomass boilers	67%	-£35 million	-£61 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

Table 6.3 PD scenario: approaches to meet the GLA target

Approach	NPV per tonne of CO_2 saved	Peabody NPV per tonne of CO_2 saved
Solar Thermal	-£148	-£305
Heat pumps	-£185	-£261
District Heating	-£100	-£228
Communal	-£130	-£255
Biomass	-£137	-£255
Decanting	-£141	-£298
Solar PV	-£347	-£450
Good Confidence	-£148	-£267
Rapid Good Confidence	-£160	-£280
Renewables	-£320	-£413
Maximum	-£314	-£369

Table 6.4 PD scenario: cost-effectiveness of approaches to meet the GLA target

6.1.4. Breaking Down

Meeting the GLA target is highly challenging in the Breaking Down scenario.

Taking the Renewables approach as a starting point, if the constraint on decanting residents is removed, emissions reductions to 2025 can be increased from 51% to 56.5%. If Biomass boilers are installed instead of CHP this increases to 60%. If an Advanced Fabric package is applied, emissions reductions for this case can be increased to 62%. This is the limit of reductions that can be achieved in the Breaking Down scenario through Peabody's efforts alone.

Therefore only two refurbishment approaches are considered for this scenario (table 6.5), a Maximum approach comprising all effective carbon reduction measures (except Advanced Fabric) and an Advanced Fabric approach where this approach is also included.

An approach that gives a good level of confidence that the 2025 target is met does not exist for this scenario, as modelled emission reductions beyond 62% would be required.

The costs of both of the above approaches are substantial, with an NPV for Peabody of -£150 million for the Maximum approach, and -£310 million for Advanced Fabric. The NPV per tonne of CO_2 saved is - £463 for the Maximum approach, and beyond -£1000 for the Advanced Fabric approach (table 6.6), far in excess of the values identified for the SD and PD scenarios.

Overall, for this scenario there is not a good degree of confidence that the approaches considered would be successful at meeting the 2025 target, and the financial viability of the approaches is in any case seriously doubtful.

Approach	Description	CO_2 Emission Reductions	NPV	Peabody NPV
Maximum	Fabric with decanting; District Heating; Biomass Boilers; Solar	60%	-£120 million	-£150 million

	PV; Solar Thermal			
Advanced Fabric	Advanced Fabric; District Heating; Biomass Boilers; Solar PV; Solar Thermal	62%	-£280 million	-£310 million

Table 6.5 BD scenario: approaches to meet the GLA target

Approach	NPV per tonne of CO_2 saved	Peabody NPV per tonne of CO_2 saved
Maximum	-£463	-£577
Advanced Fabric	-£1,027	-£1,137

Table 6.6 BD scenario: cost-effectiveness of approaches to meet the GLA target

6.1.5. Approaches for meeting the 2025 target

Bringing together the findings discussed above using the framework of the four scenarios used in this research, it is possible to reach some more general conclusions on the viability of Peabody meeting the GLA's 2025 target for carbon reduction.

It is firstly clear 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 target being met.

Two key external factors affect the emission reductions that can be achieved: resident demand for energy and the availability of low carbon energy (electricity or district heating). Without at least a halt in the current trend for increased demand for electricity and a significantly lower-carbon grid, Peabody can not meet the 2025 target.

If these conditions are in place to some degree, as they are for the SD and PD scenarios, the extent of refurbishment required depends on the extent of emission reductions already achieved by external factors.

For the scenarios considered is this research, where behaviour change and deployment of renewables is certainly optimistic, but not extreme, fairly extensive refurbishment is required to be confident of meeting the 2025 target. All solid-walled estates are insulated (with residents being decanted on estates in conservation areas to achieve this), up to 25% of estates are connected to district heating networks and renewable installations are also necessary to some degree.

Greater efforts by householders or UK government to reduce emissions would reduce Peabody's refurbishment requirement and allow only more cost-effective measures to be employed. With beneficial external change, insulation improvements alone could be sufficient for Peabody stock.

Conversely, if the burden to reduce emissions falls more on physical improvements to Peabody stock, less cost-effective measures such as solar PV will be necessary. This would greatly increase the challenge for Peabody of funding refurbishment.

There is significant uncertainty around the extent to which some of the measures studied can be deployed in Peabody stock. Use of biomass in central London may be constrained and district heating may not be available to the levels assumed. If this is the case, technologies such as solar PV and solar thermal could be deployed to reduce emissions instead, but would be likely to significantly increase costs.

6.1.6. Bridging the funding gap

The NPV results have demonstrated that each refurbishment approach that leads to the GLA's target being achieved has a significantly negative NPV, indicating a funding gap that needs to be bridged by Peabody if any of the approaches studied are to be carried out.

Additional funds of the order of tens of millions of pounds may be challenging to generate through existing stock refurbishment budgets or by reducing budgets from other services. If existing internal resources are insufficient to fund this refurbishment, two principal options remain for Peabody — increasing rents or disposing of properties.

In this section the implications of funding refurbishment through either of these approaches are explored. The results presented are intended to be illustrative of the implications of meeting the GLA target, and are not intended to represent recommendations for funding strategies.

Background and methods

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.

The annual rent increases (that go beyond this level) that would be required during the period 2011 to 2030 to give a zero NPV for Peabody for each successful refurbishment approach have been calculated. Whilst this illustrates the level of increases that would be required to fund the considered refurbishment approaches, it is acknowledged that this approach is not currently viable in the current regulatory climate.

Where sales of Peabody stock are considered, it is assumed for simplicity that dwellings 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. Disposals of properties are currently planned to take place at Peabody as part of its asset management strategy, and these sales represent extra disposals beyond planned levels.

Results

Results are presented for the three scenarios where strategies for meeting the GLA target were identified (tables 6.7 to 6.9).

For the SD scenario, the approaches considered require annual rent increases in the range 0.4% to 0.9% or between 290 and 730 sales of dwellings. To meet the target with a good degree of confidence, an annual rent increase of 0.7% or sales of 520 dwellings would be required.

For the PD scenario, the range of rent increases or stock sales required to meet the 2025 target is lower: an annual rent increase of 0.2% to 0.7% or between 210 and 720 units sold. The Good Confidence approach would require annual rent increases of 0.4% or sales of 360 units.

	Biomass	Decanting	Solar PV	Renewables	Good Confidence	Rapid Good Confidence	Maximum
Rent Increase	0.4%	0.6%	0.6%	0.7%	0.7%	0.8%	0.9%
Stock Sales	290	430	460	520	520	590	730

Table 6.7 SD scenario: funding methods to meet the GLA target

	Solar Thermal	Heat Pumps	District Heating	Communal	Biomass	Decanting
Annual rent increase	0.3%	0.2%	0.2%	0.3%	0.3%	0.3%
Stock sales	250	220	210	240	250	330
	Solar PV	Good Confidence	Rapid Good Confidence	Renewables	Maximum	
Annual rent increase	0.5%	0.4%	0.6%	0.6%	0.7%	
Stock Sales	500	390	560	560	720	

Table 6.8 PD scenario: funding methods to meet the GLA target

	Maximum	Advanced Fabric
Annual rent increase	1.0%	2.0%
Stock sales	1050	2050

Table 6.9 BD scenario: funding methods to meet the GLA target

For the BD scenario, the costs of meeting the GLA target are much more prohibitive. If costs were met through stock sales, 1050 sales would be required for the Maximum approach and 2050 for the Advanced Fabric approach. If rent increases were used, annual increases of 1% and 2% respectively would be required.

Discussion

The results show that the scale of extra funding required is significant, but is not necessarily prohibitive in every scenario.

For the SD and PD scenarios, annual rent increases between 0.2% and 0.9% or between 210 and 730 sales of dwellings are required to fund the approaches put forward. To give the figure for stock sales context, Peabody's current disposals programme, which is designed to provide funding to meet the Decent Homes standard, involves sales of approximately 600 units from 2006 to 2010.

To give the rent increase figure some context, the National Housing Federation has called for Government legislation on rent increases to be changed, permitting increases of 1% a year beyond inflation rather than 0.5% a year (National Housing Federation 2007). The further 0.5% increase would, for example, enable the Good Confidence approach in the Power Down scenario to be funded.

It should be noted that this increase was called for by the National Housing Federation as it was seen as necessary to fund further construction of new housing, rather than stock refurbishment (ibid). This implies that there would be competing demands on any increased rental income, and a potential need to increase rents beyond the figures given here to meet both goals.

Increasing rents towards target rents

Rents for Peabody residents are generally lower than for comparable social landlords in London (Housing Corporation 2008). Government legislation on rent restructuring demands that rents in social housing should move towards Target Rents, specified using a Government formula, so that rents are at Target Rent levels by 2012 (ODPM 2003).

In Peabody's case, due to currently low rent levels, this requires an increase in average rents. However, due to restrictions in the rent restructuring legislation described above, less than a third of Peabody homes are expected to be let at target rents by 2012 (based on information from Peabody).

The maximum limit on potential extra rental income available to Peabody can be identified by calculating the extra income (relative to current projected income) that is generated by a hypothetical instant move to target rents.

Using figures from Peabody, this move would generate extra income of £223 million up to 2030. By applying a discount rate to the increased cash flows, this income has a present value (in 2008) of £149 million with a discount rate of 3.5%, £176 million with a 2% discount rate or £187 million with a discount rate of 1.5%.

Therefore, in every case the income generated comfortably exceeds the extra funds required to pay for stock refurbishment that meets the 2025 target for the SD and PD scenarios.

Clearly an instant increase to target rents would not be viable and could be detrimental for residents. However, this result implies that a staged increase at levels beyond those currently permitted by Government could theoretically be used to bridge the funding gap. In so doing, Peabody could be able to fund stock refurbishment without causing undue hardship for residents.

6.1.7. Beyond the 2025 target

The 60% emission reduction goal set by the GLA is a milestone on an intended trajectory to still-greater emission cuts of the order of 80-90%, with further rapid reductions intended from 2025 to 2030 (GLA 2007).

Furthermore, the evidence that there is greater potential to achieve deep emission cuts in less efficient stock such as Peabody's could imply that landlords such as Peabody should look to achieve reductions beyond any given percentage target applied to the housing sector. This also implies a need to assess the viability of achieving cuts that go beyond the GLA target.

Although new technologies may play a significant role in the period up to 2025 and afterwards in achieving emission cuts, the results from this research can be used to judge the viability of achieving emission cuts of 80% or beyond using existing technologies.
The greatest emission reductions achieved to 2030 for the initial modelled approaches was 72% for the Renewables approach in the PD scenario (table 3.2). The Maximum approach for the PD scenario (described in 6.1.3) achieves an 85% reduction by 2030, assuming that all gas central heating systems are removed and replaced with electric heating.

These results highlight that to go beyond the 2025 target, towards reductions in the range 80-90%, substantial further stock improvements may be required, which would need to include less cost-effective technologies such as solar PV.

Emission targets on this scale would also put greater pressure on constraints external to Peabody, such as planning policies in conservation areas, levels of domestic energy use and the emissions associated with grid electricity.

6.2. Achieving Zero-Carbon

An estate can be described as zero-carbon if the net carbon emissions on-site — that is, any emissions caused by on-site energy use subtracted by any emissions offset due to on-site energy generation — are zero or less (CLG 2007).

This onsite-only definition as applied to new dwellings has been challenged by the UK Green Building Council (UK Green Building Council 2008). They have suggested that offsite generation could be permitted if it was demonstrated to provide genuinely additional renewables capacity, or that emissions could be offset by paying into a carbon trading scheme or Community Energy Fund. If this definition was used, then Peabody stock could be made zero-carbon regardless of on-site emissions, if sufficient funds were available to offset on-site emissions.

For this research, the current Government approach, that zero-carbon status should be achieved through on-site measures only, has been used to evaluate the potential for Peabody stock to be zero-carbon.

To consider the prospects of achieving zero-carbon status for Peabody's stock as a whole and for the 21st Century Community Estates, the most successful emission reduction scenario, Power Down, is taken as a starting point. The improvements that need to be made beyond this starting point to achieve net zero carbon emissions are then considered.

6.2.1. Estates achieving zero-carbon status in the Power Down scenario

After the application of the Renewables approach in the Power Down scenario, one Peabody estate achieves zero carbon emissions in 2030 (Hainton Close), having annual emissions per unit of minus 0.1 tonnes. This is achieved through an assumed connection to a district heating scheme, and a substantial installation of solar PV, which produces more electricity annually than is used on the estate (and is all exported to the grid).

As energy derived from fossil fuels is either directly or indirectly supplying all Peabody estates in 2030, the approach that provided net zero emissions for Hainton Close, of offsetting emissions through generation of on-site electricity with solar PV, is required for any other Peabody estate to be zero-carbon.

The principal barrier to achieving this in Peabody stock is the relatively small amounts of roof space suitable for solar PV on its estates. This is especially the case on Peabody's older estates, which are multi-storey and often have heavily shaded roofs, leading to a low area of roof space per dwelling. Only a fraction of this roof space will then by appropriately oriented for solar panels to be efficient, making the available area smaller still.

6.2.2. Achieving zero-carbon estates by 2030

The ability for the Peabody stock and the 21st Century Community estates to go beyond the levels of reductions described above using existing technologies will depend on three key assumptions: the carbon intensity of grid electricity; energy demand from residents; the viability of biomass CHP.

Biomass CHP is important as it is the only technology apart from solar PV and gas-fired CHP that can be used on Peabody estates to offset emissions through the generation of electricity. At present, it is not considered to be a mature technology for applications on the scale of Peabody estates (Renewables Advisory Board 2007), but this situation could change by 2030.

To assess the impact of reduced demand and reduced emissions from lower carbon communal heating, such as heating through biomass CHP, four approaches are considered (table 6.10). The emission reductions achieved by 2030 through these approaches are shown for each of the 21st Century Community estates and the stock as a whole in table 6.11.

The results indicate that even if maximum use is made of technical interventions and with significant energy demand reductions from residents, zero-carbon status is not achieved for Peabody stock as a whole or for any of the 21st Century Community estates.

Base	in which the assumptions in the Renewables approach of the PD scenario are used.
Maximum	As for the Maximum approach in 6.1.3 above. Furthermore, it is also assumed that gas boilers are replaced with electric storage heaters (as with the carbon intensity of grid electricity being below 0.2 gCO_2 /kWh in 2030 in each case, this is the lowest carbon option). It is also assumed that gas cookers are replaced with electric cookers in each home where gas heating is removed for the same reason.
Low Demand	As for the Maximum approach, but with resident demand for energy reduced to the lower limit used in the sensitivity analysis.
Low Demand and Biomass CHP	As for the Low Demand approach, but with biomass CHP installed instead of biomass boilers

Table 6.10 Approaches to achieve zero net carbon emissions

Approach	Fort St	Peabody Hill	Pembury	Rosendale	Wild St	ALL ESTATES	% emission reduction
Base	0.6	1.4	0.9	1.7	0.8	1.0	71%
Maximum	0.6	0.8	0.4	0.9	0.6	0.5	85%
Low Demand	0.4	0.6	0.3	0.7	0.4	0.4	89%
Low Demand and Biomass CHP	0.4	0.6	0.03	0.7	0.4	0.3	91%

Table 6.11 Average annual emissions in 2030 for 21st Century Community estates and whole stock

A remaining approach to achieve zero carbon emissions would be to assume a reduced carbon intensity of grid electricity, beyond the already low figure for 2030 of 0.171 kg CO_2 per kWh (around 1/3 of present-day levels).

However, reducing this figure towards zero does not lead to zero net carbon emissions being achieved. This is because when the emissions associated with electricity use are reduced, the carbon emission reductions that result from displacing grid electricity by on-site generation (through solar PV or biomass CHP) are also reduced.
This leads to the conclusion that zero-carbon grid electricity is necessary to achieve zero carbon emissions, coupled with a modified approach to energy supply systems on Peabody estates.

Zero-carbon grid electricity

If grid electricity is produced entirely from zero-carbon sources, then if any fossil fuels are used either directly or indirectly to provide energy for Peabody estates, zero-carbon status can not be achieved.

Consideration of zero-carbon grid electricity can lead to results that seem counter-intuitive. For example, the Hainton Close estate described in 6.2.1 above which achieves zero-carbon status in the PD scenario, loses this status as the carbon intensity of grid electricity approaches zero. This is due to the reduced effectiveness of displacing grid electricity and the continued use of natural gas as an input to the district heating scheme.

To achieve zero net carbon emissions in the context of a zero-carbon grid using existing technologies requires the exclusive use of electricity or biofuels to provide energy for Peabody estates.

Gas-fired individual heating systems could be replaced by electric heating, either in the form of storage heaters or, where feasible, heat pumps. Communal systems could only be used as part of a zero-carbon solution for the whole stock if they could be fuelled entirely by biofuels, such as wood-chip or biogas, and did not rely on gas-fired backup boilers as is currently common practice (CIBSE 1999).

As the availability of biofuels is likely to be insufficient to provide for all heating needs in London (Building Design 2007), there is therefore a risk that the development of communal infrastructure, although effective at reducing emissions over the lifetime of the communal boilers, may not be a beneficial investment with a view to a longer term goal of achieving zero net carbon emissions across the Peabody stock.

6.2.3. Discussion

For the whole Peabody stock to be zero-carbon by 2030, zero-carbon grid electricity is required. This conclusion holds even if biomass CHP is used where possible to supply energy to Peabody estates.
Given this extremely challenging requirement, there is no package of measures that can be recommended to Peabody to achieve zero stock carbon emissions through its own efforts.

If zero-carbon grid electricity were available, any Peabody estate would be zero-carbon if all energy came from electricity, even if no reductions in energy demand took place to 2030. However, decarbonising the electricity supply will be considerably more difficult without demand reduction (CAT 2007). As a result, insulation and micro-generation measures are likely to still be required for Peabody homes to assist with efforts to reduce energy demand.

If such a goal can be achieved, the context is likely to be one of an extremely strong effort to decarbonise the UK economy, such as that outlined in the Zero Carbon Britain report published by the Centre for Alternative Technology (CAT), which sets the goal of a zero-carbon UK by 2027 (ibid). Zero-carbon grid electricity was called for in the CAT report, and close to zero-carbon grid electricity in 2030 has also been called for by the UK's Committee on Climate Change to help achieve an 80% reduction in UK emissions by 2050 (Committee on Climate Change 2008).

The scale of the effort required to develop a zero-carbon grid in the UK by 2030 is substantial. In recent research, Cambridge Econometrics claimed that based upon current and projected policies, the 2020 EU target of 15% of final energy demand in the UK being met by renewables, was likely to be missed by a wide margin (Cambridge Econometrics 2008). The report called for a step-change in renewable deployment to meet the 2020 target. Action to provide zero-carbon electricity in the UK by 2030 goes some way beyond this challenging goal.

7. CONCLUSIONS & RECOMMENDATIONS

In this chapter, the main conclusions from this work are summarised, and some recommendations for Peabody and policymakers based on the research findings are put forward.

7.1. Conclusions

The main findings of this report are summarised here with reference to the three research aims put forward in chapter one.

1. Identify the viability of achieving deep cuts in carbon emissions from existing Peabody homes

Deep cuts in carbon emissions were assessed using two targets —the GLA's target for emission reductions in London for 2025, and the goal of achieving zero net carbon emissions for Peabody stock by 2030.

Of the four scenarios modelled, the GLA's target for 2025 can only be met with a good degree of confidence in the Sustainable Development and Power Down scenarios. This is due to the strong reliance on reductions in carbon intensity of grid electricity and reduced energy demand from residents.

The extent of stock refurbishment required depends significantly on these external factors. For the two scenarios above, comprehensive solid wall insulation, connections to district heating networks and some deployment of renewable technologies are required.

The analysis of cost-effectiveness of refurbishment measures indicates a preference for solid-wall insulation, connection to district heating networks and installation of biomass boilers on estates over micro-generation options and gas-fired CHP. Micro-generation measures such as solar PV, solar thermal and heat pumps do however become more cost-effective in scenarios where Government offers them significant financial support.

The stock investment and spending required by Peabody to meet the 2025 target can be increased or decreased significantly by the extent of emission reductions that are brought about due to factors outside of its control, such as by more renewables feeding in to the national grid. If progress on emission reduction external to Peabody is slow, extensive use of measures such as solar PV and solar thermal would be required, adding significantly to the expenditure required.

Refurbishment on this scale, making significant use of technologies such as solar PV, may be needed in any case for Peabody to go beyond 60% reductions by 2025 towards reductions of the order of 80% or 90% in later years.

For Peabody stock to achieve zero-carbon status, a radical change in the generation of grid electricity is required, so that it is produced entirely from zero-carbon sources by 2030. The technical viability of this goal is uncertain, although a report by the Centre for Alternative Technology has outlined a broad approach for achieving this in the UK by 2027 (CAT 2007).

The political viability of this goal is even more doubtful, as achieving this would require radical changes in the perceived level of action required to mitigate climate change from both the public and Government, and strong co-ordinated action by Government and industry, going far beyond any level of action planned at present.

In a context of the availability of zero-carbon electricity, Peabody stock could technically achieve zero-carbon status by simply being powered entirely by electricity. However, in practice, substantial demand reduction is likely to be required to make a zero-carbon UK viable. To play its part in this demand reduction, it is likely that Peabody stock would need a comprehensive programme of solid wall insulation and installations of solar thermal and solar PV where viable. Electricity could be used for supplying heat more efficiently by the installation of both ground and air source heat pumps where viable. Any communal heating systems would need to be fuelled entirely by biofuels, such as wood or biogas.

2. Identify the conditions under which carbon emission reduction targets are met

The key conclusion on the conditions required to meet carbon reduction targets is that Peabody can not achieve deep emission cuts from their stock through their efforts alone.

This conclusion is in agreement with the position set out in the GLA's 2007 Climate Change Action Plan, which stated that whilst the 2025 target was technically achievable, no realistic strategy for meeting the target was achievable without regulatory and policy changes at the national level (GLA 2007).

To meet the GLA's target, substantial reductions in the carbon intensity of grid electricity are required, alongside reductions in resident energy demand. To achieve zero net carbon emissions, all grid electricity used by Peabody must be generated from zero-carbon sources.

It was found that in a context of very strong action on climate change in the UK, Peabody can still meet the GLA's target whilst maintaining the external appearance of estates in conservation areas and avoiding the cost and disruption of re-housing residents whilst estates are refurbished.

However, if greater emission cuts need to be achieved through technical improvements to Peabody stock, the pressure to remove these constraints increases. This is particularly true for the approach of decanting residents to install internal insulation, which is found to be a more cost-effective measure than micro-generation, and more beneficial in terms of reducing resident fuel bills.

To achieve emission reductions that go beyond 60% towards 80% or 90% using existing technologies is likely to require the use of micro-generation technologies such as solar PV and air source heat pumps on estates in conservation areas, creating a potentially difficult trade-off.

The conditions under which zero carbon emissions can be achieved for Peabody stock are radically different to socio-economic conditions in the UK today. A context in which Government commits to generating all electricity from renewables by 2030 is likely to be one where carbon emission reduction and energy saving is a dominant goal in UK society, and would require a step change in current approaches to respond to the issue of climate change.

3. Identify the financial implications of measures taken by Peabody — both for Peabody and its residents

The key result regarding the financial impacts of refurbishment is that each approach considered that meets the GLA target has a negative overall net present value. This result also holds for each individual measure considered, including insulation improvements, communal heating and solar thermal.

This indicates that even where the reduction in fuel bills achieved by refurbishment is taken into account, Peabody and its residents are financially worse off overall when each approach is carried out.

This result also demonstrates that if rents were increased after refurbishment so that residents' savings could be used to subsidise Peabody's investment costs, this would not generate enough funds to make investment cost-neutral for Peabody. If refurbishment was paid for wholly by rent increases, residents would be worse off overall.

This situation contrasts sharply with the context of carbon reduction refurbishment over previous decades. Measures such as cavity wall insulation and draught-proofing have typically led to fuel bill savings over the long term, making refurbishment beneficial both financially and in terms of emission reduction.

This implies that carbon reduction refurbishment would bring with it a need for increased expenditure that Peabody's current funding model 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), through the sale of Peabody stock or through reducing spending on other Peabody services and operations.

The scale of the funding gap is of the order of tens of millions of pounds, with the magnitude depending on the approach to refurbishment used. For the two scenarios where Peabody is able to meet the 2025 target with a good degree of confidence, further funding of the order of £50 - £80 million would be required. These figures assume significant grant support and financial incentives for micro-generation technologies, which reduce the funding shortfall by approximately £30 million.

The implications of raising funds to meet the GLA's 2025 target through stock sales or rent increases were investigated for this research. Depending on the extent of refurbishment required, annual rent increases in the range of 0.2% to 0.9% per annum (leading to an overall increase of between 4% and 19% by 2030), or sales of between 210 and 730 homes would be needed to bridge the funding gap.

Rent increases could be an appropriate 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.

If permitted by Government, faster convergence towards target rents at Peabody could generate sufficient extra income to fund the more-extensive refurbishment options considered in this research. If this option remains unavailable to Peabody, sales of stock would be likely to be required to fund refurbishment to significantly reduce emissions.

For Peabody residents, this research indicates a potential increase in the prevalence of fuel poverty, due to the assumption that fuel costs increase in real terms to 2030 for all scenarios.

If Peabody's planned approach to refurbishment is carried out, fuel poverty levels increase from the 2008 level of 3% in each scenario. For this approach, around 6% of Peabody residents are in fuel poverty in 2030 for all scenarios except Breaking Down, where the assumed high fuel costs lead to over 25% of Peabody households living in fuel poverty.

Applying solid wall insulation on Peabody estates (either externally, or internally in void dwellings for estates in conservation areas) reduces the prevalence of fuel poverty by around half in each scenario, leading to no net increase in fuel poverty levels to 2030 for all scenarios except Breaking Down.

The viability of eliminating fuel poverty on Peabody estates by 2016 was assessed by considering the impacts of a rapid programme of fabric improvements, such that all solid-walled dwellings are insulated by that date. Although this approach brought fuel poverty levels close to zero by 2016 in each scenario except Breaking Down, they increase again towards 2030.

This implies that if fuel prices remain close to present-day levels, Peabody can virtually eliminate fuel poverty on its estates through insulating all its homes. If fuel prices rise significantly, as is assumed in the Breaking Down scenario, then it will be difficult for Peabody to intervene to prevent a significant fraction of Peabody households from being in fuel poverty.

7.2. Recommendations

In this section some recommendations arising from this research are presented, both for Peabody and policymakers, which would facilitate the achievement of deep carbon emission cuts in Peabody stock.

Practical action

Over the short term Peabody should look to gain further experience of the refurbishment measures that have been identified as important for the achievement of deep emission cuts. This would add to Peabody's knowledge base on the practical and economic factors affecting each measure, give improved knowledge of the emission reductions that can be achieved, and help to identify the views of Peabody residents on the considered measures.

This can be done most efficiently by identifying estates which are already due for refurbishment or maintenance work, and incorporating further carbon reduction measures alongside it.

Solid wall insulation is the most important measure identified by this research. As a first step, Peabody should consider identifying estates that can receive solid wall insulation in addition to planned Decent Homes work over the next few years. Ideal candidate estates would be those that are representative of archetypes of Peabody stock.

It would be useful to identify at least two estates so that Peabody can carry out both internal and external insulation. This work would present an important research opportunity, and it would be greatly beneficial to Peabody and the wider housing sector to monitor energy use in the treated homes before and after refurbishment to identify the impact of the insulation improvements.

Peabody should also look to gain experience of converting an estate currently fuelled by individual heating systems to a communal system. The most likely opportunity would be through estates with potential to connect to a nearby district heating system.

If estates can be identified with sufficient space to make an on-site communal biomass system technically feasible, this option is also worth pursuing. Research by Dwyer (2007) indicates that this may be the case for Peabody's Camberwell Green estate.

Peabody does not yet have experience of solar thermal technology, so opportunities to install this technology should also be sought. An ideal opportunity would be if both re-roofing works and central heating replacement are planned through the Decent Homes programme for any existing Peabody estates.

Over the longer term, Peabody should consider a comprehensive programme of solid wall insulation for their stock, ideally basing their decision on whether to proceed on the results of refurbishments carried out over coming years.

The case for some of the other technical options considered for this research depends upon changes in context over coming years.

Electric heating technologies could play an important role over the next two decades if significant grid decarbonisation is achieved. However, due to the increase in fuel bills they could bring about, Peabody should wait until good progress on grid decarbonisation is achieved before considering switching homes to electric heating.

The case for communal heating depends upon the long-term prospects for a particular site to move beyond gas-fired CHP towards a significant proportion of zero-carbon fuel inputs. Peabody should assess possible district heating connections, or estate-level communal heating, with this consideration in mind.

Finally, the extent of deployment of solar micro-generation technologies ultimately depends upon the level of emission reductions Peabody choose to pursue for their existing stock. As these measures are relatively costly, a useful first step would be for Peabody to plan to at least consider their installation when planned re-roofing works are due to take place. In this way, installations could potentially be carried out when marginal costs are lowest.

Organisational change

This research has demonstrated that approaches to refurbishment that can bring about deep emission cuts require expenditure that exceeds Peabody's planned long-term spending.

As a result, if funding is to be made available for the measures described above it is likely to require an organisational commitment from Peabody to achieve deep reductions in emissions from its stock.

Such a commitment would bring with it a reframing of Peabody's responsibilities towards the homes they manage. 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.

A commitment could take a more tangible form through an emission reduction target, a SAP target (minimum and/or average), or as a commitment for all Peabody homes to have adequate insulation. A target of this nature may be forced upon social landlords through regulation in any case if Government carries out some of the policy recommendations that have been put forward for achieving emission cuts in existing housing.

Alongside any commitment to act should come further analysis of the financial impacts of refurbishment and the identification of a funding strategy. As was the case with the Decent Homes standard, such a strategy could significantly change Peabody's long-term financial plans.

Peabody should also look to actively develop capacity to successfully manage carbon reduction technologies such as CHP or solar PV which require new ways of working. An Energy Service Company (ESCo) approach may be useful in this context, so that the management of low-carbon technologies across Peabody stock can be handled by specialised staff.

External change

Change external to Peabody has been shown to be vital if deep carbon emission cuts are to be achieved. Significant decarbonisation of the grid is a key issue and the targets put forward by the Committee on Climate Change (2008) for substantial grid decarbonisation offer a useful goal to work towards. To support the decarbonisation of existing housing, Government should actively work towards this goal.

A viable funding strategy for Peabody could involve the ability to increase rents, but this is not possible in the current regulatory context. Much prior work on carbon reduction in housing has identified this barrier, and this research supports the idea that Government should allow some flexibility for landlords to raise rents to offset refurbishment costs.

Residents' demand for energy is another crucial issue. Whilst this is dependent to a large degree on broad social causes, Peabody can still support its residents to use less energy by actions such as providing quality advice on using efficient use of heating systems and making electricity feedback monitors available to residents that request them. For Government, any policies that can help reduce domestic energy demand will be of great importance. A wide range of interventions such as a rapid roll-out of smart meters, regulations on appliance efficiency and the use of financial incentives such as personal carbon trading would each have a valuable impact.

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