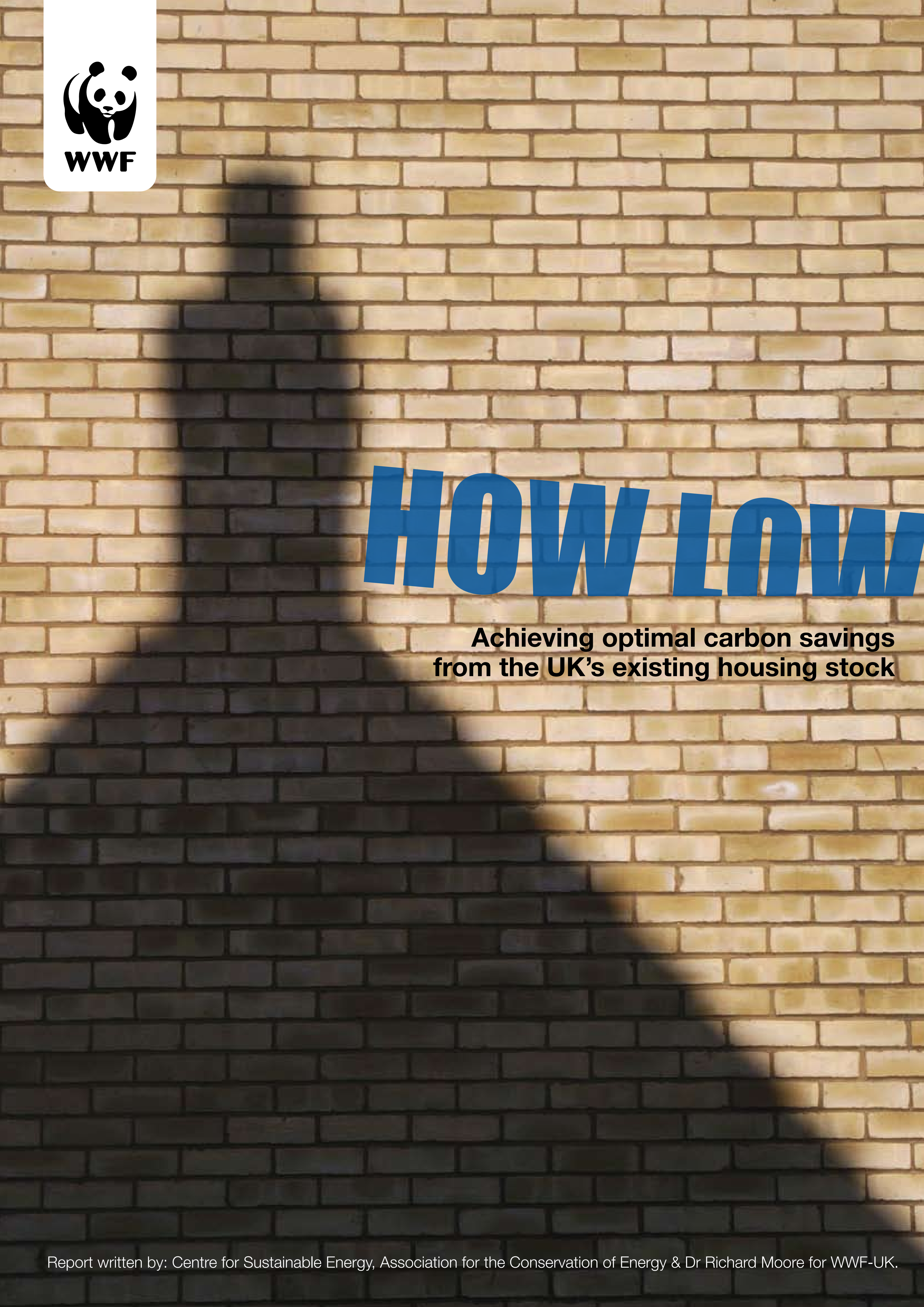


HOW LOW

Achieving optimal carbon savings from the UK's existing housing stock

Report written by: Centre for Sustainable Energy, Association for the Conservation of Energy & Dr Richard Moore for WWF-UK.

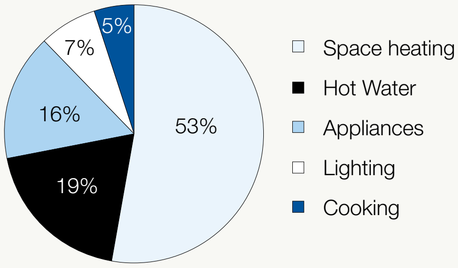
contents

1 Executive summary

1.1 Home energy use

Over 27% of the UK's carbon dioxide (CO_2) emissions come from the residential sector.

Figure 1: **Source of these emissions by end use**[1]



27% of the UK's carbon dioxide emissions come from the residential sector.

Many of the measures which will enable us to make the necessary deep and significant cuts in these emissions also improve the quality of our homes and will reduce energy bills. It is clearly vital to tackle this area appropriately, and as a matter of urgency.

1.2 What must be achieved?

The government's National Energy Efficiency Action Plan (NEEAP[2]) sets a target to reduce emissions from the UK's residential housing stock by 31% on 1990 levels by 2020. Further, the government's own Climate Change Bill contains a legally binding economy-wide target to reduce CO_2 emissions by at least 60% on 1990 levels by 2050.

We need a wholesale revision of the rate and efficacy with which the environmental impacts of the UK's housing stock are tackled. The government's current housing policies are overly fragmented and will not deliver the cuts in CO_2 emissions necessary to achieve its own targets[3].

This was acknowledged by Prime Minister Gordon Brown in the 2007 Budget statement which announced that the government would ensure that by 2020 all homes would meet their cost-effective energy efficiency potential. However this definition of 'cost- effective' looks only at short term payback and does not factor in any value for the cost of carbon.

1.3 Why has this study used a cut of 80%, not 60%, by 2050?

This study had used the most up-to-date 80% target for a reduction in emissions from the UK residential sector.

The overwhelming scientific consensus is that the Climate Change Bill's 60% target is inadequate to avert the worst ravages of climate change. It is essential that atmospheric greenhouse gas concentrations are stabilised at a maximum of 450 parts per million (ppm)[4] of CO_2 equivalent to avoid irreversible and extremely damaging climatic changes. This would require all developed countries to cut emissions by at least 80% from 1990 levels by 2050[5].

ONE PLANET FUTURE

If everyone in the world were to consume natural resources and generate carbon dioxide (CO_2) at the rate we do in the UK, we would need three planets to support us. WWF has a vision for a One Planet Future – a world where everyone lives in harmony with nature and thrives within their fair share of the Earth's natural resources. It is a vision that requires a transformation in the way we live.

1 UK Energy Efficiency Action Plan – Defra, 2007 2 (Defra 2007a); Defra's NEEAP covers energy efficiency measures, renewables and carbon emissions 3 Those targets under the National Energy Action Plan (NEEAP) or the residential sector portion of the Climate Change Bill targets. 4 International symposium of the stabilisation of greenhouse gas concentrations, Hadley Centre, 2005 5 See, for example, Höhne, Phylipsen and Moltmann (2007)

1.4 What must policy-makers do to implement this?

The study has shown that urgent government action is needed to ensure the UK meets its targets for residential carbon emissions, and to ensure it is on track for 80% cuts in the sector by 2050. The study examines the measures, market transformation and behavioural changes needed to achieve these targets. In short:

- In order to achieve the UK's 2020 targets we will need to go beyond the short payback energy efficiency measures that feature in current policies. We will need to deploy significant numbers of low and zero carbon technologies (LZC) and solid wall insulation.
- The government must act now to ensure that the 80% reduction is achieved. This requires a strong set of supporting policies and financing mechanisms that support the deployment of sustainable energy measures.

This set of policy measures should include:

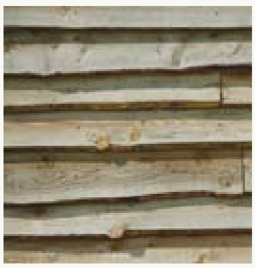
1.4.1 Fiscal incentives

It is vital that the government employs a suite of economic instruments to encourage the development of more energy efficient homes (and sustainable homes more widely). The poor rate of take-up of many short payback measures highlights the lack of public understanding of, and buy-in to, their necessity. The palette of financial measures should include, but not be limited to: a stamp duty rebate on energy efficiency improvements made within a year of moving into a property; a national Council Tax rebate scheme; and cutting VAT on the refurbishment of existing properties.

1.4.2 Low interest loan scheme

In Germany, borrowers are able to take out low interest loans for measures that help older properties reach new-build standards through refurbishment. On reaching this standard, the government repays 10% of the loan to the householder. This government-supported retrofit programme has been extremely successful. The UK government must explore how to indroduce such innovative financing mechanisms that support the refurbishment of existing buildings.

In order to achieve the UK's 2020 targets we will need to go far beyond the short payback energy efficiency measures that feature in current policies



We need to deploy significant numbers of low and zero carbon technologies (LZC) and solid wall insulation.

1.4.3 Supplier Obligation, post-2011

The government is currently consulting on the Supplier Obligation, namely if it should be an upstream trading mechanism, a downstream measures-based approach or a hybrid[6]. The government must ensure that the Supplier Obligation takes into account the shadow price of carbon which would ensure all policy decisions take due consideration of their environmental impacts. It must also support the deployment of both solid wall insulation and LZC technologies, which are not provided for under the current mechanisms, in significant numbers.

1.1.4 Minimum standards at point of sale, 2010 to 2016

The government should ensure that a minimum standard is set and progressively tightened to transform the housing sector, by preventing the resale (or letting) of the most energy-inefficient homes. For example, with appropriate exemptions, by 2016 no property with an Energy Performance Certificate rating of E could be resold, a target that can be achieved with the most cost-effective measures for the majority of properties.

1.4.5 Reform the energy market

Feed-in tariffs are a recognised method of encouraging the installation of electricity from micro-generation in countries such as Germany and Spain. They ensure that the householder can get a fixed and substantial price for electricity they generate and feed in to the National Grid. The government should ensure that the public are guaranteed that this price reflects the true cost of installing the equipment.

1.4.6 Evaluate personal carbon trading (PCT) or carbon taxes, 2013 to 2015 onwards

UK residential emissions have not decreased since 1990. Our relationship with energy use and personal understanding of carbon emissions needs to evolve if we are to meet our 2020 and 2050 targets. The government must open the debate to include a wide range of potential policy measures, including personal carbon trading and carbon taxes. It must ensure that the social implications of both trading and taxation approaches are fully understood – i.e. who stands to lose and gain.

However, there are significant barriers to introducing PCT, and it could not be onstream for several years. As it is imperative to act now, any debate on these mechanisms must be in parallel with the other recommended actions. Particularly important is to consider how PCT might interact with other measures so as to understand the most effective way forward. For example, emissions can't be capped upstream and downstream simultaneously, it is therefore important that any overlap between the supplier obligation and PCT is planned carefully.

1.5 What has been explored?

The project team has considered what the "cost-effective" savings from the UK residential sector are. The carbon savings have been modelled for the implementation of two cost-effective scenarios to 2020. These scenarios are:

- **1a** the **market potential**, as defined by the government's limited definition of cost-effective[7]; and
- **1b** the **economic potential**, as defined by any measures that recoup their upfront costs by future bill savings over their lifespan[8].

The latter approach, which is the report team's recommended and pragmatic approach, significantly increases the number of measures deemed cost-effective, resulting in more measures being applied and increased carbon and financial savings.

The project team has not included a cost of carbon in either of these models as this will be released as an associated piece of work. However it is noted that even using a relatively low cost of carbon will significantly increase the number of measures considered 'cost effective.' This is just one of the ways in which the project team has been deliberately cautious in its assumptions.

6 In a hybrid system, emissions would be capped and tradable among suppliers, with a seperate measures-based social obligation for low income households. 7 This was defined solely as including: cavity wall, loft and hot water cylinder insulation, draught proofing, efficient boilers and heating controls. 8 The Treasury's own discount rate of 3.5% was used to determine this.

The 2050 scenarios, 2a and 2b, have examined what can be achieved if all available measures are applied to the residential sector, regardless of whether they achieve net financial payback. Considering the scale of the challenge, it is likely that almost everything possible will be needed to achieve 80% cuts. Scenario 2b includes stronger assumptions about the additional reduction in carbon emissions achievable from things other than measures applied to the property itself. These include a greater decarbonisation of the energy supply and more efficient appliances.

1.6 How (and why) this report uses conservative assumptions

The study has made a number of conservative assumptions about the technologies that have been applied and the magnitude of savings generated. This approach should reassure readers that the savings we present are achievable with concerted government action. Furthermore, the costs of the measures required and the magnitude of the savings generated represent the pessimistic scenario. The measures associated with scenarios 2a and 2b more than pay for themselves if projected system costs are used and the full payback is included – i.e. Gross Value Added (GVA)[9], lifetime fuel savings and value of carbon.

The following is a short description of the main conservative assumptions made in this report. See Annex VI for more detail.

1.6.1 Discount rates and cost of carbon

Scenario 1b represents a cost-effective scenario based upon a Treasury (real) 3.5% discount rate for the savings achieved. The study could have alternatively looked at those measures deemed cost-effective when the cost of carbon has been added. This definition of cost-effective would be even more holistic than that used for scenario 1b, and even more measures would have been available.

1.6.2 Areas of Outstanding Natural Beauty

The *How low?* study has assumed that solar power systems and internal/external wall insulation will not be applied systematically to listed buildings or to homes in conservation areas.

1.6.3 Green gas percentage

The study has considered methods of future decarbonisation of energy supply. The report team has made a conservative assumption of a total residential green gas supply of 10% by 2050.

1.6.4 Decarbonisation of electricity

The report team has linearly extrapolated the projected carbon intensity of delivered electricity (2008-20) to estimate a 2050 carbon factor of 0.059kgC/kWh. The recent IPPR, RSPB and WWF[10] study – *80% Challenge* – to identify whether it would be possible to reduce the UK's carbon emissions by 80% of 1990 levels by 2050 identified decarbonised electricity as a key measure – i.e. a carbon factor of 0.005kgC/kWh. This study has not assumed as high a level of decarbonisation as the *80% Challenge* report, which serves to highlight that there is room to manoeuvre and go beyond an 80% cut in the residential sector.

1.6.5 Measures costs – mass marketing LZC technologies

The report team has used a cost based on today's prices for insulation and LZC technologies, which are likely to fall significantly between now and 2050. The Renewables Advisory Board examined the projected cost of LZC technologies from 2007 to 2025. If the cost reductions predicted are applied to scenario 2, to 2050, costs fall by £36 billion which would mean that they achieve a net positive economic position.

1.6.6 Fuel prices

This represents a conservative estimate of the actual savings achieved, as the fuel prices are based on 2007 averages. Whereas DTI baseline projections for fuel prices by 2020 demonstrate an average price rise of 21%.

1.6.7 Measures lifetimes – 15 years

The study has assumed a 15-year lifetime for all measures. This is a conservative estimate based on the shortest lifetime among the measures applied. The insulation measures and solar power systems typically have a 20-30 year lifetime. If a 20-year lifetime were applied, the lifetime savings would increase by 33%.

9 Gross Value Added represents value to the UK economy or money in the pockets of British workers and businesses. 10 www.wwf.org.uk/filelibrary/pdf/80percent_report.pdf

1.7 How low can residential emissions go?

The government's definition of cost-effectiveness, is overly restrictive and as a result only achieves emissions reductions of 22% from 1990 levels. As shown in Scenario 1a, this falls short of both the National Energy Efficiency Action Plan (NEEAP) and Climate Change Bill targets (apportioned to a household sectoral target for these purposes). This demonstrates that a more holistic view of cost-effectiveness must be considered if we are to meet our 2020 residential carbon emission targets.

Our alternative definition of cost-effective – scenario 1b – could reduce UK residential emissions by a further 7%, which exceeds both the Climate Change Bill targets and those for 2020 from the NEEAP. The scenario requires the deployment of significant numbers of solid wall insulation and low and zero carbon (LZC) technologies, for which adequate provision is not made under current implementation or funding policies. Implementing these measures by 2020 will require the government to support a step change in the capacity to install them. For example, implementing scenario 1b would require in the region of 125,000 solar water heating systems to be installed each year, a tenfold increase on current activity.

Concurrently, the government will need to implement the above range of supporting fiscal and behavioural change policies to educate and provide incentives for householders to take action. Householders need to have a better understanding of their own energy use and carbon emissions and a vested interest in taking those measures.

It is noted again that scenario 1b does not include a cost of carbon which would make even more measures cost effective by 2020.

The 80% reduction in residential emissions by 2050 is achievable under scenario 2b. This requires: the implementation of the sustainable energy improvements to homes described in 1b; an uplift in the energy efficiency of household appliances; a reduction in the carbon content in electricity through improved generating efficiencies and increased large scale renewable energy generation; the use of green gas from waste or other organic matter; and a 20% improvement in people's behaviour to further reduce home energy use. In order to implement scenario 2b by 2050, we will need to first implement scenario 1b. Given the urgency of the issue, we suggest that the government implements a strong set of policies now to facilitate this by 2020.

Table 1: Summary of emissions reductions for all scenarios

Year		**2020** (MtC)	% reduction		**2050** (MtC)	% reduction
Government targets	NEEAP	29.3	**31%**	Climate Change Bill	8.5*	**60%**
Market potential (Scenario 1a)		33.1	**22%**			
Economic potential (Scenario 1b)		27.7	**35%**			
Technical potential (Scenario 2a)					11.9	**72%**
Theoretical potential (Scenario 2b)					8.5	**80%**

*Although the Climate Change Bill does not contain sectoral targets, this has been apportioned to the residential sector.

Table 2: Summary of measures costs, savings and benefits under the home improvement model

	Scenario 1a (2020)	**Scenario 1b (2020)**	**Scenario 2a & b** (2050)**
Savings calculated by the model (MtC)	6.2	9.5	11.2
Total costs*	£23.1	£92.5	£156.0
Total economic benefit lower	£80.9	£108.3	£111.8
Total economic benefit upper	£84.3	£113.6	£118.0
Net benefit (lower)	£57.8	£15.9	-£44.2
Net benefit (upper)	£61.2	£21.1	-£38.0

* All figures in billions

** This table only considers savings and costs under the model, without considering the wider improvements around decarbonisation of energy supply, appliance efficiency and behaviour change. Therefore scenarios 2a and 2b are the same.

1.8 What are the benefits?

Table 2 summarises the carbon savings associated with all the measures applied to individual properties, their cost and overall economic benefit. The savings are conservative as they do not include those associated with improved appliance efficiency, behavioural changes and upstream changes to the energy mix of fuels. Scenario 1a would generate over £3 of fuel savings for every £1 spent on home improvements. The total economic benefit if scenario 1b was implemented by 2020 also outweighs the projected cost. These measures will also provide considerable benefit to the 3.5 million fuel-poor households in the UK[11], thus helping the UK government to achieve its statutory target to eradicate fuel poverty where practicably possible in all homes by 2016.

For scenarios 2a and 2b, implemented to 2050, the total benefit is less than the investment cost, but this takes the very conservative position that LZC technologies will not fall in price. However, if the predicted cost of LZC technologies falls, in line with the Renewables Advisory Board (RAB) projections the economic benefit therefore matches the investment made even without ascribing a cost of carbon. The cost of £2.6-£3.5 billion per year required to deliver the residential sector measures in scenario 2b is minimal compared to the cost of doing nothing. The Stern Review[12] estimated the cost to the economy of mitigating the harmful impacts of climate change to be 10 times that of acting now.

1.9 What are the implications for the sustainable energy sector in the UK?

The study has concentrated on the capacity to deliver sustainable energy measures to homes between 2007 and 2020, as the government's support mechanism and intentions beyond this date are entirely unknown. In order to achieve our UK 2020 NEEAP targets we will need to implement scenario 1b.

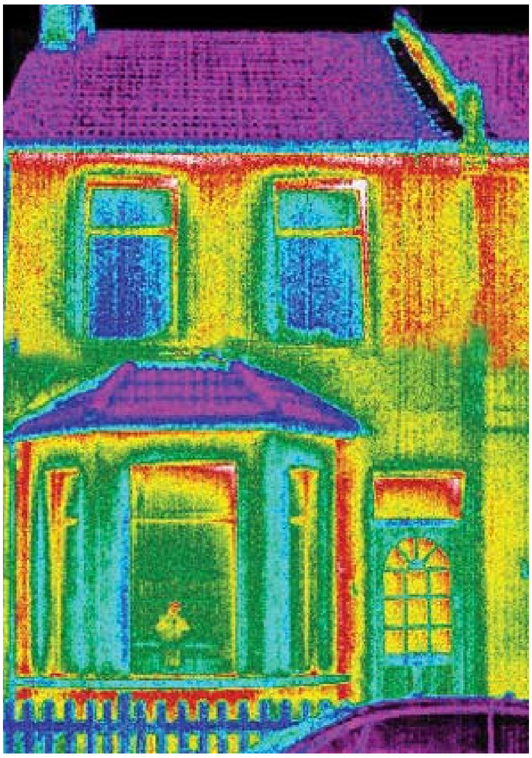
Current installation rates fall short of the required rates for all solid wall insulation measures and renewable energy measures. The shortfall suggests a significant programme of training, investment and policy support would be needed if the required installation rates are to be achieved.

The greatest uplift is needed in micro-combined heat and power (CHP) installation, which requires an increase of just under 685,000 installations per year. Micro-CHP is a near-market-ready technology and the government must ensure that a framework is put in place to facilitate its deployment across the housing sector. If the government ensures that this and similar technologies are developed and successfully deployed in the UK in large numbers, then we will be well positioned globally as market leaders in emerging and expanding markets. Micro-CHP also has an important role to play in balancing our future energy needs. It matches supply and demand, by producing electricity when the grid most needs it, i.e. predominantly in the mornings and evenings when we are at home using our heating systems.

1.10 How have the improvements been modelled?

The Improvement Model that underpins the study has been developed by CSE, ACE and Dr Richard Moore over the last two years. The sophisticated computer model draws together geographically specific data from the English House Condition Survey (EHCS) and data on sustainable energy improvements from ACE's Fuel Prophet Model (which includes fuel type and savings data). This is integrated with data from the devolved administrations to build the nationwide picture.

The Stern review estimated the cost to the economy of mitigating the harmful impacts of climate change to be 10 times that of acting now.



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11 EEPfH, *The impact of fuel price risees in the managed housing sector,* CSE, ACE and Dr Richard Moore 2007. 12 www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

2 Background

The UK government's 2007 budget presented the aim that: "by the end of the next decade, all householders will have been offered help to introduce energy efficiency measures with the aim that, where practicably possible, all homes will have achieved their cost-effective energy efficiency potential"[13]. This study, entitled How low? for short, takes this statement as its starting point and examines the level of carbon dioxide (CO_2) emissions reductions that are feasible within the UK housing stock by 2020 using 'cost-effective' measures.

The report also assesses what longer-term action is required to ensure the requisite stability in carbon emissions is achieved by 2050. It is now widely accepted that stabilising atmospheric greenhouse gas concentrations at a maximum of 450 parts per million (ppm) of CO_2 equivalent is necessary[14] to avoid dangerous climate change. This would require all developed countries to cut CO_2 emissions by at least 80% from 1990 levels by 2050[13]. Therefore, this study examines the feasibility of achieving an 80% cut in emissions by applying certain measures to the UK's housing stock.

The UK government's own Climate Change Bill contains a legally binding target to reduce CO_2 emissions by at least 60% from 1990 levels by 2050. This target was first suggested by the Royal Commission on Environmental Pollution, which identified the need to stabilise global concentrations of CO_2 at an upper limit of 550 ppm[16] to limit warming to 2°C. Based on every country in the world emitting its 'fair share' by 2050, this would require the UK to cut emissions by 60% from 2000 levels – a greater cut than that proposed in the Climate Change Bill. However, the 60% figure used in the Climate Change Bill is based on out-of-date science and, as stated, there is now consensus across the scientific community that an 80% cut is the minimum required.

3 How low do we need to go?

Since more than 27% of the UK's CO_2 emissions come from domestic housing, this is clearly a vital sector to tackle. The UK's residential sector greenhouse gas emissions were 45.8 megatonnes of carbon equivalent (MtC) in 1990, of which 42.4Mt were CO_2[17].

The UK government has made a number of announcements and commitments to reduce CO_2 emissions (see Table 3). Most recent of these is the National Energy Efficiency Action Plan (NEEAP[18]), which sets a target to reduce emissions from the UK's residential housing stock to 29.3MtC (a 31% reduction) by 2020. With the exception of the UK Climate Change Bill target, the remaining targets shown in Table 3 are not statutory.

At present, the UK Climate Change Bill does not contain sectoral targets. However, applying the Bill's overall 60% target proportionately to housing would mean reducing emissions to 17MtC by 2050[19]. Achieving an 80% cut would require us to reduce residential emissions to 8.5MtC. As with the 60% target, an 80% reduction of the UK's total emissions would need to be achieved across all sectors. This may ultimately mean that further cuts in the residential sector would be required to offset emissions growth (or smaller cuts) in other areas, such as from aviation. Indeed, if international aviation and shipping were to be included in the Climate Change Bill carbon budget targets, then we would have to follow an even steeper downward trajectory for residential emissions, which could have knock-on implications for the utility of the fuel mix (see Decarbonised electricity, section 6.2).

Table 3: Summary of UK residential sector emissions targets (MtC)

Year	UK residential sector greenhouse gas emissions	UK residential sector CO_2 emissions
1990 baseline	45.8	42.4
2004 emissions	43.7	41.7
Targets[20]		
2008-12 (Kyoto)	40.1	n/a
2010 (CCP 2006)	38.6	37.6
2010 (NEEAP)	n/a	37.7
2010 (Gov target)	n/a	33.9
2016 (NEEAP)	n/a	33.1
2020 (NEEAP)	n/a	29.3
2020 (UK Climate Change Bill)	n/a	28.8 – 31.4
2050 (UK Climate Change Bill)	n/a	17
2050 (80% cut)	n/a	8.5

13 HM Treasury (2007). 14 International Symposium on the Stabilisation of greenhouse gas concentrations, Hadley Centre, 2005. 15 See, for example, Höhne, Phylipsen and Moltmann (2007). 16 RCEP (2000). 17 Defra (2006). 18 Defra (2007a); Defra's NEEAP covers energy efficiency measures, renewables and carbon emissions. 19 This figure is calculated on the current basis that international aviation and shipping are not incorporated into the targets. 20 Statutory residential sector targets or proportional allocations of wider targets.

4 How low scenarios – selection and limiting criteria

The study has examined the impact of four scenarios on carbon emissions from UK housing stock. The key selection criteria for each scenario were:

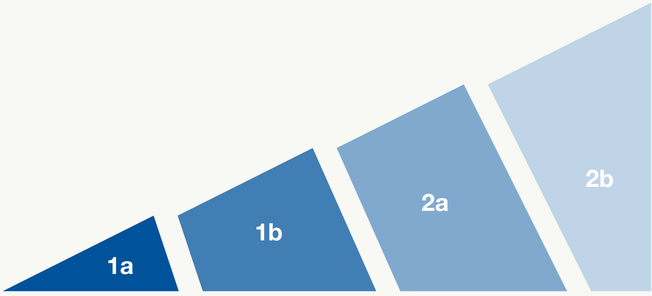
Scenarios to 2020:

- Scenario 1a – The government's pledge on cost-effective measures, defined by the then Chancellor Gordon Brown in the 2007 Budget statement.
- Scenario 1b – Going beyond the basics on a firm financial footing – i.e. the measures deemed cost-effective by the team's analysis of measures, and packages thereof, that have a positive net present value (NPV, see Annex II).

Scenarios to 2050:

- Scenario 2a – Doing all we can – i.e. all measures applied by the model.
- Scenario 2b – Additionally, going further in reducing emissions from areas not covered by the model, such as stronger assumptions about the decarbonisation of the energy supply.

Figure 2: Different levels of potential emissions cuts and relationships of the scenarios



1a Market potential
1b Economic potential
2a Technical potential
2b Theoretical potential

The four scenarios should not be viewed as alternatives, but rather each subsequent scenario requires virtually all the same activity as the scenario numbered before it, but does more to achieve greater emissions reductions. Each scenario broadly represents a different level of potential emissions cuts to either 2020 or 2050. The relationship between the scenarios and the levels of emissions reductions is further illustrated in Figure 2.

4.1 Limiting Criteria

The different types of potential are explained, along with the descriptions of each scenario, in section 5.

The mix of sustainable energy measures applied under each scenario was subjected to a set of criteria that limited their application to suitable locations and situations. The model accounts for the local vernacular and landscape – for example, if the building is listed or situated in an Area of Outstanding Natural Beauty (AONB).

4.1.1 AONBs and Listed Buildings

- External wall insulation is not selected for listed buildings with solid walls or homes in a conservation area.
- Internal wall insulation is not selected for individually listed buildings with solid walls and/or where the habitable rooms are already small.
- Solar hot water (SHW) and photovoltaic (PV) installations are not selected for flats or houses/bungalows in AONBs[21].

4.1.2 Demolition and replacement

The study does not specify any demolition and any additional new build beyond business as usual, as the demolition and replacement costs are up to 10 times[22] more than those for refurbishment. Unfortunately there is a zero rate of VAT on new build, compared to 17.5% VAT on refurbishment and this actively encourages developers to opt for the more destructive option. In terms of the energy balance between demolition and new build, there are varying schools of thought, but rigorous reuse of materials and aggregates through effective interpretation of planning locally is one way of minimising the additional energy use and emissions embodied by new construction. It should also be noted that there can be multiple external drivers affecting the case for refurbishment in preference to demolition and rebuild, such as community cohesion and place-making.

21 It could be argued that planning restrictions in AONBs need to be eased. For the purpose of this study, a number of assumptions have been made that err on the side of caution. For an outline of these, see Annex VI. 22 SDC (2007).

5 The Scenarios outlined

5.1 What is deemed cost-effective by 2020?

5.1.1 Scenario 1a (2020) – market potential

Scenario 1a modelled the implementation of measures in the housing stock based on the “intention” stated in the 2007 Budget that, “by the end of the next decade, all householders will have been offered help to introduce energy efficientcy measures with the aim that, where practicably possible, all homes will have achieved their cost-effective energy efficiency potential”. The measures seen as cost-effective in the Budget include “cavity wall, loft and hot water cylinder insulation, draught proofing, efficient boilers and heating controls”[23]. Scenario 1a models these measures, including low energy lighting and assuming ‘efficient boilers’ to include gas, oil and LPG condensing boilers, as being installed in all applicable[24] dwellings[25].

In principle, this scenario represents what is taken to be the *market potential* for emissions reductions – i.e. reductions in emissions that in theory should come about with little to no government intervention because they are highly cost-effective. In practice, for many reasons including public apathy and a lack of buy-in as to their environmental necessity and benefit, these measures are often not taken up in a free market system.

5.1.2 Scenario 1b (2020) – economic potential

Scenario 1b was developed according to two criteria. The first was to consider individual measures or combinations of measures to be cost-effective if they carried a positive net present value over their lifetime. The second was not to include micro-wind turbines. The discount rate used was the Treasury’s own (real) discount rate[26] for appraising public policy – 3.5%. This more pragmatic definition of cost-effectiveness significantly expanded the measures and combinations thereof[27] that were applied to the housing stock.

In principle, scenario 1b represents the economic potential for reducing emissions from the existing stock – i.e. cost-effective emissions reductions that are not normally achievable without government intervention because of barriers such as high initial required investment or lack of information about the economic benefits of the investment.

5.2 What is technically feasible by 2050?[28]

5.2.1 Scenario 2a (2050) – technical potential

Scenario 2a was developed to consider the potential carbon savings if all current measures, regardless of cost-effectiveness, were applied. The scenario represents a pragmatic appraisal of the carbon savings that could be achieved in the housing stock from energy efficiency and low to zero carbon (LZC) technologies. The scenario includes constrained levels of both PV and micro-wind turbine installations (see Annex I for a full breakdown of the constraints applied under each scenario).

The modelled savings associated with these measures alone thus represents the technical potential for reducing emissions from the existing stock – i.e. the emissions reductions achievable from the set of currently available technologies.

5.2.2 Scenario 2b (2050) – theoretical potential

Scenario 2b represents the *theoretical potential* for reducing emissions from the existing stock. It makes stronger assumptions than the other scenarios about less certain factors, not covered by the model. These include the volume of emissions reductions, based on improving and new technologies and behavioural change. How the assumptions for each of these factors have been made for each scenario, including 2b, is briefly outlined below.

23 HM Treasury (2007); in the How Low? model, all new boilers are assumed to be fitted with modern efficient heating controls – i.e. room thermostat, timer and thermostatic radiator valves. 24 ‘Applicable’, in the context of all modelled scenarios, means that a combination of measures installed into any one dwelling takes account of the energy improvements already present. 25 For the full set of selection criteria for all scenarios, see Annex II. 26 In economic theory, consumers value a benefit in the future less than a benefit today. Discount rates are used to take account of this.27 Individual measures in addition to scenario 1a: air- and ground-source heat pumps, external and internal wall insulation, photovoltaic panels, biomass boilers, micro CHP, solar hot water systems, double-glazing. 28 Policy makers will no doubt attempt to compare the findings of this study with those recently published in the ‘Home Truths’ report by the Environmental Change Institute for Friends of the Earth and the Co-operative Bank (Boardman, 2007). However, scenario 2a shows the savings associated with energy improvement measures alone. The main differences in measures applied are the exclusion of large scale / community CHP, the higher prevalence of heat pumps and the inclusion of residential biomass central heating rather than stoves.

6 Carbon emissions reductions not predicted by the How Low? model

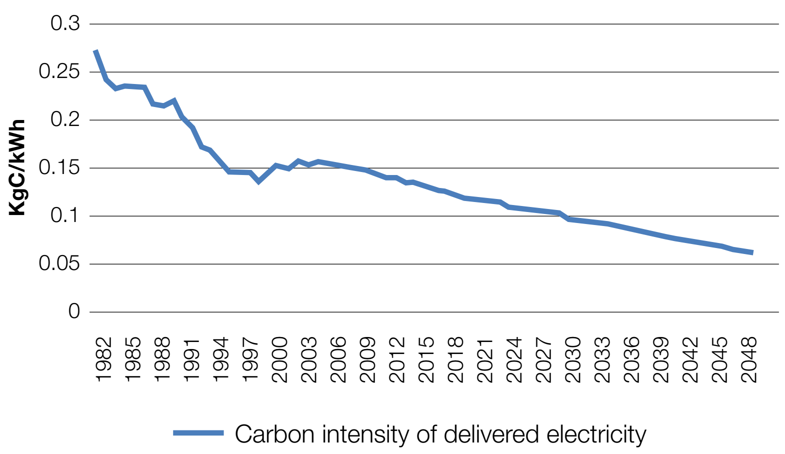
The *How Low?* model does not consider all aspects of emissions from the existing housing stock. Emissions reductions/increases not dynamically predicted by the model include:

- new build between now and 2016;
- decarbonisation of electricity;
- green gas;
- more carbon conscious energy use in the home;
- and improved efficiency of electrical appliances (other than lighting, covered by the model).

6.1 New build between now and 2016

Based on the Energy Savings Trust's published figures, the study has assumed total emissions of 1.9 MtC[29] for new homes built in the UK between now and 2016. Under current legislative plans, all new homes built from 2016 onwards will be zero carbon[30] and should therefore impose no additional carbon burden. It is possible that future new build design may further reduce carbon impacts, resulting in homes that produce more energy than they use over the year, with the excess flowing back into the wider system, but that has not been accounted for here, as it is outside the scope of this report.

Figure 3: Projected decarbonisation of electricity



6.2 Decarbonised electricity

Decarbonising electricity reduces the amount of carbon released for each kWh used in the home and requires the source of generation to be either: renewable; or low carbon and / or technically innovative – for example, carbon capture and storage (CCS) technologies applied to gas- and coal-fired power generation plants. The team has linearly extrapolated the projected carbon intensity of delivered electricity (2008 to 2020)[31] to estimate a 2050 carbon factor of 0.059kgC/kWh – as shown in Figure 3.

The vision of decarbonised electricity has been significantly bolstered by the government's recent commitment to investigate the deployment of up to 7,000 offshore wind turbines by 2020. Just 2% of the UK's energy comes from renewable sources, and wind is the source for less than half a gigawatt (GW). The government hopes that it could provide around 33GW by 2020[32].

By 2020, renewable energy should account for 20%[33] of the EU's final energy consumption (8.5% in 2005). To meet this common target, each Member State must increase its production and use of renewable energy in electricity, heating and cooling, and transport. The UK is obliged to increase its share of renewable energy from less than 2% now to 15% of the country's total energy needs by 2020. This will require a large proportion of our electricity to come from renewables (40%-50%).

The recent *80% Challenge* study by the IPPR, RSPB and WWF, to identify whether it would be possible to reduce the UK's carbon emissions by 80% of 1990 levels by 2050, identified decarbonised electricity as a key measure[34]. The study used two models: the MARKAL-MACRO model, used for 2007's Energy White Paper; and a model developed by Professor Dennis Anderson of Imperial College for the Stern Review.

Both these cost minimisation models concluded that it is feasible to reduce the UK's emissions by 80% by 2050, at costs that are not prohibitive.

29 Zavody (2007). 30 CLG (2007). 31 Market Transformation Programme (MTP) published figures for carbon content of electricity, 1980 to 2020. 32 BERR (2007); 33GW includes the 8GW already planned. 33 Council of the European Union (2007). 34 IPPR, WWF and RSPB (2007).

The models do this mainly by decarbonising electricity supply, in particular through the use of carbon capture and storage (CCS) to make fossil fuelled power generation carbon-free, and on and off-shore wind power. For reasons of caution (see Annex VI) this study has not assumed as high a level of decarbonisation as the *80% Challenge* report, which serves to highlight that there is room to manoeuvre and go beyond an 80% cut in the residential sector[35].

6.3 Green gas (for heat)

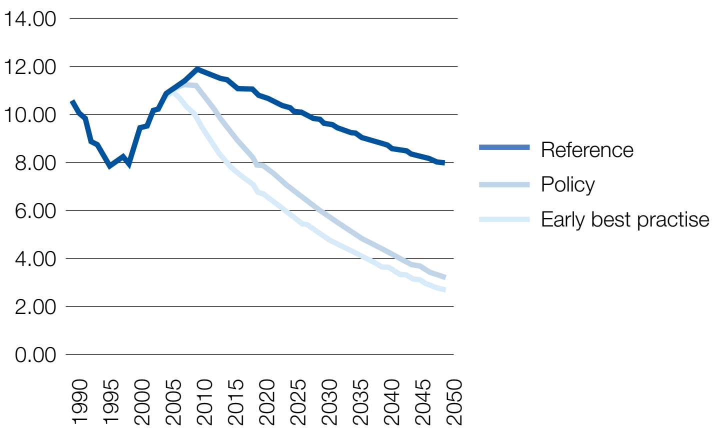
Green gas would be produced from the treatment of waste and the anaerobic digestion of agricultural organic matter and/or landfill. This gas could then be injected into the natural gas grid network. Green gas could be sold to householders in a similar way to green electricity, with householders paying for an equivalent amount to that used in their own home. It would be necessary to ensure these green gas tariffs were certified to robust standards of compliance to agreed standards.

Ernst & Young's recent examination of the initial business case for supporting the UK renewable heat sector did not examine the feasibility of biogas injection to the domestic gas supply network. However, a response to the Renewable Heat Obligation consultation by Panthol Ltd[36] (a supplier of domestic oil and biofuels) stated that the UK could possibly secure 10% of its current natural gas energy needs, or 15% of its current electricity needs, by 2020, through the production and use of biogas from indigenous UK agricultural output. This study has therefore made a moderately conservative assumption of a total residential green gas supply – of 10% by 2050.

6.4 Behavioural change and improved efficiency of appliances

Assumptions about the improved efficiency of UK electrical appliances by 2050 (other than lighting, as lighting is dealt with by the *How Low?* model) were based on the Market Transformation Programme's[37] 'Early Best Practice' scenario (extrapolated from 2020 to 2050) – as shown in Figure 4.

Figure 4: Market Transformation Programme scenarios for household electrical appliances other than lighting, extrapolated to 2050



As regards the impact on emissions of more carbon conscious behaviour in the home, it was assumed that behavioural change could reduce remaining emissions (i.e. after all of the above) by 5% – 20%[38 39], depending on the scenario.

Carbon conscious behaviour in the home could reduce remaining emmissions up to 10%.

35 This would increase carbon savings in 2050 by 3MtC. 36 Panthol Ltd (2007). 37 Funded by Defra, the Market Transformation Programme 'supports UK government policy on sustainable products. Its aim is to achieve sustainable improvements in the resource efficiency of products, systems and services where these are critical to the delivery of government commitments in areas including climate change, water efficiency and waste reduction' (MTP, 2008). 38 Not 5% of the 1990 baseline emissions.
39 This estimate is based on a review of the literature on direct feedback from metering, billing and energy displays – carried out for Defra by Oxford University's Environmental Change Institute – which was between 5% and 15% of energy demand (Darby, 2006).

6.5 In summary

Table 4 summarises the assumptions made for each of the above factors not dynamically modelled under the four scenarios.

Table 4: Assumptions made for each scenario

Additional savings	Scenario 1a ('market potential')	Scenario 1b ('economic potential')	Scenario 2a ('technical potential')	Scenario 2b ('theoretical potential')
New build between now and 2016	1.9 MtC	1.9 MtC	1.9 MtC	1.52 MtC*
Decarbonisation of electricity	n/a	n/a	0.059kgC/kWh	0.059kgC/kWh
Green gas (heat)	n/a	n/a	n/a	10% of overall grid gas supply
Improved efficiency of appliances	MTP 'Policy' scenario in 2020	MTP 'Early Best Practice' scenario in 2020	MTP 'Policy' scenario in 2050	MTP 'Early Best Practice' scenario in 2050
Behavioural change	Government predicted savings	5% of remaining emissions	10% of remaining emissions	20% of remaining emissions

Scenario 2b assumes a 20% improvement in the efficiency of new homes built before 2016 by 2050 – i.e. improved appliances.

7 Analysis of cost-effectiveness

There are many different definitions of cost-effectiveness, depending on which parameters are used. The definition used can result in widely differing outcomes as to the packages of measures which may fall within the remit of what would be applied. WWF believes that we should incorporate a cost for carbon into the definition of cost-effectiveness, to properly account for the environmental impacts of the housing sector.

Indeed, government policy is such that a carbon price should be used to inform all policy decisions, including in the existing homes arena[40]. This would greatly increase the number of carbon-saving measures applied, taking us further, faster, in terms of environmental and financial savings. But for reasons of practicality and caution, we have used a more conservative definition of cost-effective (see Annex VI).

The cost-effectiveness of different packages of sustainable energy measures for these purposes was established by calculating the net present value of each package using the Association for the Conservation of Energy's Fuel Prophet[41] to model costs and benefits in different types of representative dwellings. The model covers combinations of six built forms, five main heating fuels and three wall construction types – representative of 97.2% of all households. Net present value assesses the cost versus the benefit of an investment. When benefits exceed costs over the lifetime of the installed sustainable energy measures, the package in question has a positive net present value (NPV), and is thus deemed cost effective.

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Costs in this context are the installed cost of the sustainable energy measures, including any annual maintenance cost of the installed equipment. Benefits are the savings on energy bills over the years and, if taken into account, the value of the carbon emissions saved.

The NPV calculations for the sustainable energy measures thus took into account three factors: one set of future energy prices (rising conservatively); three different assumptions about the value of carbon; and three different discount rates. Future energy prices were not varied, so only the effect of the latter two factors on NPV have been summarised in the table below.

The lower the discount rate and the higher the value of carbon (i.e. the direction of the arrows), the more packages of sustainable energy measures attain a positive net present value, making them cost-effective. The analysis of cost-effectiveness was primarily carried out to identify the packages to be installed under scenario 1b[42] – as indicated by the entry in the grid below. But it also confirmed that the more limited choice of sustainable energy measures deemed cost-effective by the Treasury – and modelled in scenario 1a – were selected implicitly on the basis of a less favourable definition of what is cost-effective (see Annex VI).

Though scenarios 2a and 2b pay no heed to cost-effectiveness, the analysis showed that the majority of the packages of sustainable energy measures deemed uneconomic by scenarios 1a and 1b attain positive NPV – for example micro wind turbines in some combinations, or a much wider rollout of solar thermal or PV electric panels – when value is ascribed to the carbon emissions in addition to the energy saved.

A much wider rollout of solar thermal or PV electric panels becomes cost effective when a value is ascribed to the carbon emissions, in addition to the energy saved.

40 Defra (2007b). 41 The purpose of Fuel Prophet is to help housing professionals and policy researchers decide which energy saving refurbishment measures should be supported and installed. It can calculate the performance of various measures, both individually and in combination, in a variety of typical UK dwellings and under different fuel prices conditions.

42 That is by using a more forgiving definition of cost-effectiveness than that implied by the Treasury's announcement (HM Treasury, 2007) that 'by the end of the next decade [...] all homes will have achieved their cost-effective energy efficiency potential'.

Table 5: **Analysis of measures approaching positive net present value**

Increasing number of packages attain positive NPV

Increasing number of packages attain positive NPV

	No value ascribed to saved carbon	Economic value ascribed to saved carbon (based on low-end EU emissions trading scheme price of carbon)[43]	Social value ascribed to saved carbon (based on value of carbon assigned by Stern Report on the economics of climate change)
10% discount rate (a typical rate used to assess commercial investments)	Packages of sustainable energy measures with positive NPV under these assumptions correspond to the measures included in scenario 1a		
3.5% discount rate (value used to assess the cost-effectiveness of public policy)	Packages of sustainable energy measures with a positive NPV under these assumptions were selected for scenario 1b		Majority of packages installed under scenarios 2a and 2b attain positive NPV
0% discount rate (assumes people value future benefits as much as benefits appropriate today)		Majority of packages installed under scenarios 2a and 2b attain positive NPV	Majority of packages installed under scenarios 2a and 2b attain positive NPV

43 A very low-end price of carbon (at €10/tonne of CO2) was used. At time of writing (11.2.08) the trading price per tonne was above €20. The price is intended to increase over time as permit allocations in the EU Emissions Trading Scheme are tightened.

How low do we go?

The results in terms of carbon savings generated for the *How Low?* study are based on those calculated for England, extrapolated to the UK level. It utilised two English Housing Condition Survey (EHCS) models that determine the effect of changes in fuel prices and improvements to energy efficiency. For Wales, Scotland and Northern Ireland the housing condition surveys contain sufficient detail to impute savings nationally (Annex IV contains a breakdown of the modelled energy savings for each nation).

8.1 Cost-effective measures – market and economic potential

The modelling summarised in Table 5 and Figure 6 shows that scenario 1a could reduce carbon emissions by 9.3MtC in the UK, or a 22% reduction in household emissions, by 2020 (on 1990 levels). The study is based on a 1990 UK emissions baseline for the housing sector of 42.4MtC. The scenario could therefore reduce UK household emissions to 33.1MtC by 2020, which falls 3.8MtC short of the 2020 National Energy Efficiency Action Plan (NEEAP) target of 29.3MtC.

Scenario 1b could reduce carbon emissions by 14.7MtC in the UK. Compared to 1990 emission levels, this scenario could therefore reduce UK household emissions by 35% (down to 27.7MtC). Implementing scenario 1b by 2020 would therefore exceed the NEEAP target of 29.3MtC by 1.6MtC. It would also surpass the upper level of cuts targeted in the Climate Change Bill. To meet its targets for carbon emissions by the end of the next decade the government will therefore need to take a more holistic view when defining cost-effectiveness.

8.2 All measures – technical and theoretical potential

Table 6 and Figure 7 demonstrate that an 80% reduction in residential emissions by 2050 is achievable under scenario 2b. Scenario 2b requires the implementation of the modelled sustainable energy improvements (the same as in scenario 2a[44]), and greater projected improvements in the efficiency of appliances, green gas and a 20% improvement in energy use behaviour. While the decarbonisation of electricity accounts for the highest proportion of the additional savings to the model, the *80% Challenge* report identified this measure as the most cost-effective way of saving carbon in the UK residential sector.

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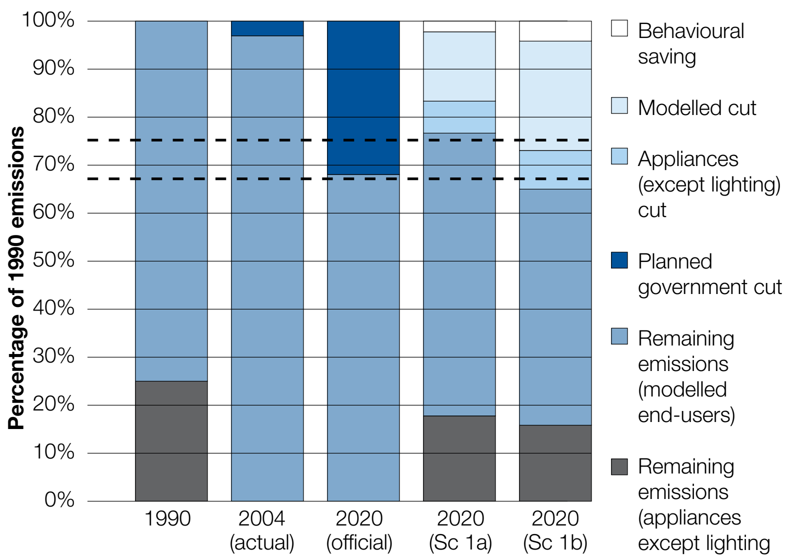
To meet its targets for carbon emissions by the end of the next decade the government needs to take a more holistic view when defining cost-effectiveness.

Table 5: Summary of emissions reductions for cost-effective scenarios in the UK (2020)

Breakdown of emissions and savings (MtC)	1990 baseline	2004 actual emissions	2020 targets (official)	2020 (1a)	2020 (1b)
Remaining emissions	42.4	41.7	29.3	33.1	27.7
Modelled energy savings					
Improved efficiency of appliances				2.7	3.8
Modelled reduction (including lighting)				6.2	9.5
Behavioural saving				0.4	1.4
Total reduction			13.1 (31%)	9.3 (22%)	14.7 (35%)

Figure 6: Emissions reductions for cost-effective scenarios in the UK (2020)[45]



44 Important note: because scenarios 2a and 2b predict exactly the same number and type of sustainable energy measures installations, they are treated collectively as 'Scenario 2' in later sections of this report.

45 The two dotted lines indicate the range of the cut envisaged by the Climate Change Bill for 2020 (at time of writing). The 2020 official cut is that envisaged for the residential sector in the UK's National Energy Efficiency Action Plan (Defra, 2007a).

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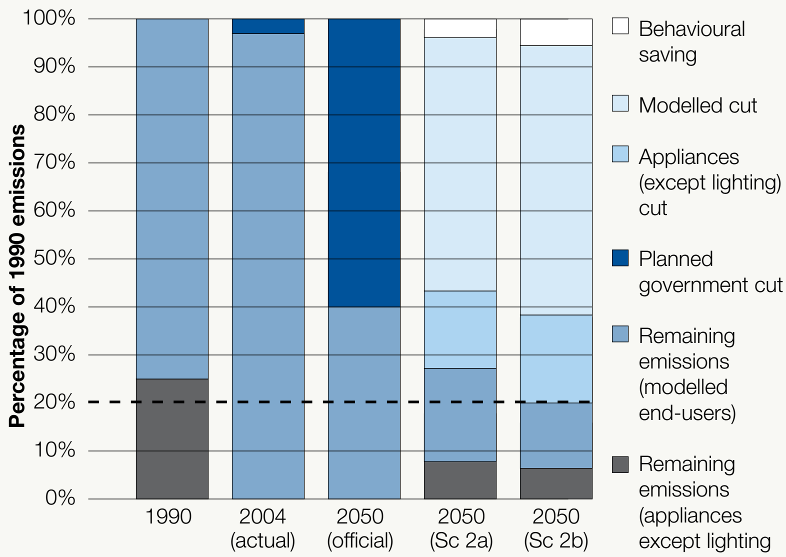
Table 6: **Summary of emissions reductions for scenario 2a and 2b in the UK**

Breakdown of emissions and savings (MtC)	**1990 baseline**	**2004 actual emissions**	**2050 targets (60%)**	**2050 (2a)**	**2050 (2b)**
Remaining emissions	42.4	41.7	17.0	11.9	8.5
Modelled energy savings					
Appliances only				7.3	7.8
Modelled reduction (including lighting)				11.6	11.6
Decarbonisation of electricity				10.7	10.7
Green gas					2.3
Behavioural saving				1.3	1.5
Total reduction			25.4 (60%)	30.5 (72%)	33.9 (80%)

Figure 7: **Long-term emissions reductions scenarios for the UK (2050)**



An 80% reduction in residential emissions by 2050 is achievable under scenario 2b.

How much to go how low?

The economic, non-energy benefit of sustainable energy activity is often ignored by researchers and policy-makers. The model outputs for the three scenarios under consideration include estimates of the total cost of installing the measures (based on a modelled average cost) and their value to the economy, or their Gross Value Added (GVA).

GVA = Turnover minus cost of bought-in materials, components and services.

GVA represents value to the UK economy or money in the pockets of British workers and businesses.

9.1 England

9.1.1 Total costs and savings for each scenario in England (all measures)

The *How Low?* model is built using information from the English Housing Condition Survey (EHCS). It is therefore possible to impute savings for other nations based on the profile of their housing stock, but it is not possible to accurately quantify the measures installed (see Annex V). The costs shown here represent the costs for measures installed in England alone. The costs for individual measures represent those costs experienced today, therefore the actual cost experienced in 2050 should be significantly lower than that shown here.

Table 7 summarises the potential total economic costs and benefits of installing the energy improvements required under all scenarios. The estimated total cost of the 46 million measures required by 2020 (including 16 million low energy light bulbs) for scenario 1a stands at just under £19 billion, with a resultant GVA of more than £5bn (see Annex I for GVA assumptions).

For scenario 1b, the number of measures required by 2020 is 42 million, with subsequent total costs of over £77 billion and a GVA of nearly £23 billion. These results show that there is considerable potential economic benefit of the proposed activity for the insulation, heating and renewables sectors. The number of measures required is lower than Scenario 1a, as lofts with 150mm or more of loft insulation are not improved. This marginal improvement is not deemed cost-effective under this scenario.

Scenario 2 requires a total expenditure of £130 billion, with a GVA of £38 billion. This cost is based on today's prices for insulation and LZC technologies, which are likely to fall significantly between now and 2050.

The recent Renewables Advisory Board (RAB) report on the 'essential role of renewables generation in achieving zero carbon homes' examined the projected cost of LZC technologies from 2007 to 2025. If the cost reductions

Table 7: Total costs and economic benefits of measures under the four scenarios in England

Scenario	Scenario 1a (2020)	Scenario 1b (2020)	Scenario 2[46]
Savings from measures alone (MtC)	5.1	8.4	9.4
Total costs	£18,970,388,000	£77,129,531,000	£129,631,485,000
Lifetime fuel savings[47]	£59,417,471,000	£69,585,329,000	£50,250,385,000
GVA (£1000s)	£5,226,526,000	£22,922,603,000	£38,995,669,000
Value of carbon – social	£5,357,051,000	£8,794,463,000	£9,894,624,000
Value of carbon – economic	£2,525,467,000	£4,145,961,000	£4,664,608,000
Total benefit (lower)	£67,169,464,000	£96,653,892,000	£93,910,663,000
Total benefit (upper)	£70,001,047,000	£101,302,394,000	£99,140,678,000
Net benefit (lower)	£48,199,076,000	£19,524,361,000	-£35,720,822,000
Net benefit (upper)	£51,030,659,000	£24,172,863,000	-£30,490,807,000

46 The carbon savings predicted by the How Low? model are the same in scenarios 2a and 2b. **47** Lifetime costs are based on 2007 fuel prices.

predicted are applied to Scenarios 2a and 2b, then the cost falls by £36 billion to £94 billion in total, which would mean that they achieve a net positive economic position.

The three scenarios summarised all demonstrate that every £3-£4 spent on sustainable energy measures in the UK result in approximately £1 generated for UK plc. In addition to this annual investment in UK industries, these households will also benefit from reduced energy bills and associated financial savings. Table 7 also shows the long-term monetary value of these savings. This represents a conservative estimate of the actual savings achieved, as the fuel prices are based on 2007 averages and a 15-year lifetime for all measures[48]. In reality, fuel prices are likely to increase significantly between 2006 and 2020, and 15 years represents the shortest lifetime of those measures applied.

Scenario 1a generates almost £3.13 of savings for every £1 of money invested in measures. These measures will provide considerable benefit to the 3.54 million[49] fuel-poor households in the UK in 2006. The *How Much?*[50] study has shown that a considerable number of LZC technologies and insulation measures will be required to alleviate fuel poverty, but there will still be a hardcore group of fuel poor that cannot be lifted out of fuel poverty by measures alone. This is due to a combination of low incomes, high fuel prices, under-occupancy and extremely inefficient housing. Under Scenario 2a and 2b it is likely that 75%-80% of households in fuel poverty would rise out of this disadvantageous position[51]. The proportion remaining would require either improved income or a change in circumstances – such as the householder moving to a smaller, more affordable property. If a cost of carbon is included in these figures, scenario 1a generates between £3.54 and £3.69 for every £1 invested. The higher figure represents a carbon cost of £70 per tonne ('social' in Table 7, left), while the lower figure represents a carbon cost of £33 per tonne ('economic' in the table)[52].

Under scenario 1b, the total benefit per £1 invested is between £1.25 and £1.31. In scenario 2, the resulting total benefit is less than £1 per £1 invested, but if the costs of LZC technologies fall, as predicted by the RAB, the resulting benefit is between £1.19 and £1.26 for each £1 invested.

48 15 years is a conservative estimate, based on the shortest lifetime of all measures applied. 49 Guertler, Moore and Preston (2007). 50 Moore, Preston and Guertler (2008). 51 As of 2006-07, approximately 16-17% of households were in fuel poverty (Guertler, Moore and Preston, 2007). 52 Stern (2007).

9.2 UK

9.2.1 Total costs and savings for each scenario in the UK (all measures)

Table 8 shows the likely cost of achieving each scenario in the UK, based on the imputation methodology for the devolved nations shown in Annex V. The total cost of £156 billion in scenario 2 equates to expenditure of £3.5 billion per year. If the RAB cost reductions for LZC[53] technologies were applied, then the expenditure would fall to £113 billion – or £2.6 billion per year. The range of annual expenditure of £2.6-£3.5 billion per year is significantly lower than the £12.9 billion required in the *Home Truths* report, but does not include the additional cost to UK plc of decarbonising electricity, which is outside the scope of this study.

At the UK level, scenario 1a provides almost £3.10 of savings for every £1 invested in measures (lifetime fuel savings divided by cost). If a cost for carbon is included in the analysis, in scenario 1a the resulting total benefit (fuel savings plus carbon savings) is between £3.50 and £3.65 per £1 invested in measures. Under scenario 1b the total benefit per £1 invested is between £1.17 and £1.23. For scenario 2, the total benefit per £1 invested is less than £1, but if the cost of LZC technologies falls in line with RAB predictions, costs for scenario 2 will fall by approximately £43 billion to under £113 billion, giving savings per £1 invested of between £0.99 and £1.05. In this instance the economic benefit therefore matches the investment made.

Table 9 and Table 10 show known current UK government investment in residential sustainable energy measures and the required investment per year for each scenario. The regional housing allocation represents an estimate[54] of the Communities and Local Government (CLG) expenditure that is made available to local authorities through the regional offices and devolved administrations. The table does not include measures funded by local authorities to meet Decent Homes Standard (DHS) targets, as they do not theoretically receive funds to implement them. It is therefore not possible to estimate the total funds allocated to energy efficiency measures by local authorities that have not been through the Large Scale Voluntary Transfer (LSVT) process i.e. they still own and maintain housing.

Table 8: Total costs and economic benefits of measures under the three scenarios in the UK

Scenario	Scenario 1a (2020)	Scenario 1b (2020)	Scenario 2
Savings for measures alone (MtC)	6.2	9.5	11.2
Total costs	£23,090,781,000	£92,471,114,000	£155,988,710,000
Lifetime fuel savings	£71,554,369,000	£76,331,708,000	£59,831,616,000
GVA	£6,221,205,000	£27,285,084,000	£46,417,073,000
Value of carbon – social	£6,537,802,000	£10,003,608,000	£11,746,150,000
Value of carbon – economic	£3,082,107,000	£4,715,987,000	£5,537,471,000
Total benefit (lower)	£80,857,680,000	£108,332,779,000	£111,786,160,000
Total benefit (upper)	£84,313,376,000	£113,620,400,000	£117,994,839,000
Net benefit (lower)	£57,766,899,000	£15,861,665,000	-£44,202,550,000
Net benefit (upper)	£61,222,595,000	£21,149,286,000	-£37,993,871,000

Table 9: Total costs achieved under the three scenarios in the UK

Scenario	Total costs	Cost per year for modelled measures
Scenario 1a (2020)	£23,090,781,000	£1,776,214,000
Scenario 1b (2020)	£92,471,114,000	£7,113,163,000
Scenario 2a and 2b	£155,988,710,000	£3,545,198,000

Table 10: Known UK government investment in the existing housing stock

	Current annual investment (UK)
Warm Front	£350,000,000
EEC-2	£300,000,000
Decent Homes	£100,000,000
LCBP (Phase 1 Stream 1)	£6,500,000
Regional housing allocation*	£551,378,000
Total	**£1,307,878,000**

53 (Element Energy & EST 2007) 54 The estimated funds are based on the share of the South West regional housing allocation which is passed on to local authorities.

The total funds available could be in the region of £1.3 billion. In reality this total will be lower, as a proportion of the regional housing allocation will be spent on general improvement rather than specific energy efficiency measures. It is also worth noting that the English regions have cut the amount of funding available for existing housing through the regional housing allocation in 2008. The regions plan to distribute a proportion of this funding stream to new affordable housing. The annual expenditure available is therefore likely to fall to approximately £1 billion. **The current funding available therefore falls significantly short of that required for all three scenarios.**

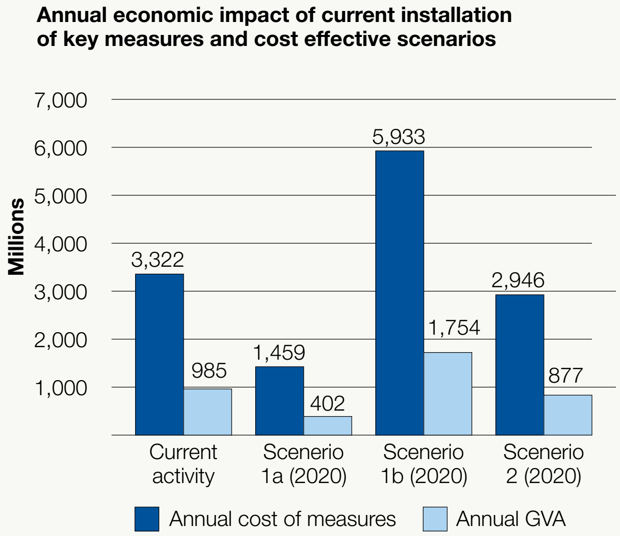
9.3 Economic benefit in England

The analysis of economic benefit focuses on England alone as the methodology used to impute savings for each scenario (see Annex V) cannot be used to generate the numbers of measures installed.

Table 11: Annual costs and economic benefits of key measures under scenarios in England

Scenario	Measures per year	Costs/yr	GVA/yr
Current (all key measures)	2,509,000	£3,321,560,000	£984,528,000
Scenario 1a (2020)	2,309,000	£1,459,261,000	£402,040,000
Scenario 1b (2020)	2,751,000	£5,933,041,000	£1,754,269,000
Scenario 2a and 2b	937,000	£2,946,170,000	£877,484,000

Figure 8: Annual costs and economic benefits of measures for each scenario in England



55 Current activity represents the cost and measures associated with the installation of all key sustainability measures in England (see Annex II for further details).

9.3.1 Total economic benefit for each scenario

The analysis of economic impact and deployment excludes both low energy lighting and double glazing. The study assumes that the government will remain committed to phasing out incandescent light bulbs after 2009, thus making the need for fiscal or regulatory support obsolete. Double glazing has not been included in the study as it is primarily a home improvement measure rather than an energy efficiency one, and as such is unlikely to attract regulatory or fiscal support.

Table 11 shows the number of measures and expenditure required per year for the key sustainable energy measures identified (excluding lighting and double glazing). The results, illustrated in Figure 8 below, have been compared with the current[55] annual costs for key sustainable energy measures.

This shows that under scenario 1a, just over 2.3 million measures are required to be installed annually, at a cost of nearly £1.5 billion. This gives an annual GVA of over £400 million. The number of measures required annually for scenario 1a is slightly lower than the current rates of installation for all key sustainable energy measures shown in Annex II (by approximately 200,000).

If scenario 1b were to be delivered by 2020, the annual number of installations required is over 200,000 higher than the current yearly figure for all key sustainable energy measures. The annual expenditure required, and the resulting GVA is nearly double that for all current key sustainable energy measures. Under this scenario, annual costs of measures need to rise by nearly £2.6 billion. This would give an additional annual GVA of approximately £1.7 billion and require a significant programme of training, investment and policy support.

Under scenario 2, costs per year and GVA per year are lower than current activity, as fewer measures – under a million measures per year – are installed. This is because it covers a longer time period and so, although the overall number of measures installed between now and 2050 are higher than the scenarios that only reach 2020, the annual number of measures installed is lower. Although it was not part of the specification of scenario 2 that every home should receive at least one LZC, on average the model shows 1.3 LZC technologies being installed per household.

How to go how low?

10.1 What increase in installation rates is required to 2020?

The study has concentrated on the capacity to deliver sustainable energy measures between 2007 and 2020, as the UK government's support mechanism and intentions beyond this date are entirely unknown. Current installation rates for the key insulation and renewable energy measures were identified using information supplied by the National Insulation Association (NIA) and data collected through consultation in relation to a previous sister project *How Much?*. Where necessary, estimates for England only were calculated from UK figures using population counts for 2003.

Table 12: Required installations per year in England

Measure	Current per year	Scenario 1a (2020) Required rate	Difference	Scenario 1b (2020) Required rate	Difference
Cavity wall insulation	378,052	174,640	203,412	257,034	121,018
Loft insulation	490,188	830,732	-340,545	330,734	159,453
Draught proofing	245,080	571,351	-326,271	370,349	-125,269
External wall insulation	16,802	-		2,852	13,950
Internal wall insulation	3,360	-		114,592	-111,232
Gas central heating	1,310,579	693,602	616,977	389,999	920,580
Oil central heating	62,589	35,639	26,949	3,291	59,297
Micro-CHP	50	-		685,050	-685,000
Ground source heat pumps	105	-		377,761	-377,656
ASHP	50	-		778	-728
Biomass boilers	44	-		808	-764
Solar PV	340	-		91,803	-91,463
Solar water heating	1,320	-		125,164	-123,844

Table 12 shows these current installation rates and the difference between these and the installation rates required under scenarios 1a and 1b. Thus a positive value indicates that current installation rates are in excess of those required, whereas a negative value shows that there is a deficit between the current and required rate of installation.

Under scenario 1a, loft insulation and draught proofing require more than an additional 300,000 installations per year each. Under scenario 1b, current installation rates fall short of the required rates for draught proofing, internal wall and all renewable energy measures included in this scenario.

The greatest deficit lies in micro-CHP (Combined Heat and Power) installation, which requires an increase of just under 685,000 installations per year. It is worth noting that micro-CHP is a near-market-ready technology. Similarly to the *Home Truths* report, we assume that the technology will be implemented post-2010. However, prior to 2010, we need to ensure that the framework is put in place to facilitate the spread of this technology across the housing sector. If the government ensures that this technology is developed and successfully deployed in the UK in large numbers, then we will be well positioned globally as market leaders in an emerging and expanding market.

The Carbon Trust's recent update on the micro-CHP field trial[56] concluded that the technology can deliver significant carbon savings if used in the right applications (see Annex II for limiting criteria used). Micro-CHP also has an important role to play in balancing our energy needs. It produces electricity when the grid most needs it – i.e. predominantly in the mornings and evenings when we are at home using our heating systems.

10.2 What installations may be possible under planned support mechanisms?

The planned support mechanisms for the installation of sustainable energy measures between 2008 and 2017 are the Carbon Emissions Reduction Target (CERT) – 2008 to 2011 – and the Supplier Obligation – 2011 to 2020. These support mechanisms have the potential to help meet the government's ambitious targets and the measures identified for scenarios 1a and 1b. The probable mix of measures supported under CERT has been published but the Supplier Obligation is in development, with further consultation expected later in 2008.

The Supplier Obligation (SO) may introduce a cap and trade system, requiring suppliers to reduce customer energy demand or carbon emissions through the acquisition of desirable customers (from a carbon perspective) and/or the application of measures. It is not clear what level of support the obligation will provide for measures, but the government has ambitious hopes for a scale of delivery that may prove challenging for an industry that will have just delivered the CERT targets. However, continuing government vacillation over the nature of the SO makes any more specific prognosis difficult.

56 Carbon Trust (2007).

The National Insulation Association (NIA) provided the study with projected totals for key insulation measures under CERT and the Supplier Obligation, based on an industry base case and accelerated scenarios for loft insulation (LI), cavity wall insulation (CWI) and solid walled insulation (SW). The NIA interpretation of a supplier obligation envisages a measure-based approach to energy suppliers achieving their targets, which runs counter to CSE's own analysis of how an energy supplier may choose to achieve its target[57]. Table 13: Total insulation measures possible by 2020 in England shows the total number of measures that would be required for each scenario and the number that the industry predicts possible by 2020.

Table 13 shows that there would be insufficient capacity to insulate all the lofts identified under scenario 1a unless the accelerated scenario for loft insulation was implemented. The number of lofts insulated under 1a is significantly higher than that for 1b as the scenario also includes the marginal top-ups of insulation required to meet building regulations (not deemed cost-effective by scenario 1b – i.e. 50mm or less). There is sufficient cavity wall insulation capacity for both scenarios. However, there is a deficiency in internal wall capacity for scenario 1b unless the national capacity for solid wall insulation is accelerated.

The project team has been unable to identify similar studies for residential heating or renewable energy capacity post CERT; however, Table 14 shows that a huge step change in the deployment of renewable energy measures would be necessary to meet the need. This would require a huge step change in supply chain, training and delivery. If the Supplier Obligation provides sufficient incentive for renewables on a large scale (post-2011) and the Low Carbon Building Programme (LCBP) continues until at least 2016, there will be further capacity for LZC technologies. However, the tightening of the regulations on new homes post-2013, when the Code for Sustainable Homes Level 4 is required, will result in significant conflicting demand for this already insufficient resource.

While CERT does include uplift for renewable technologies, Table 12 shows that with the exception of biomass boilers there are insufficient numbers of installations per year to meet what is required for scenario 1b. Furthermore, ASHPs and micro-CHP are not included in the current mix of measures covered.

Table 13: Total insulation measures possible by 2020 in England

Loft insulation	**Total**	**External wall insulation**	**Total**
Scenario 1a (required)	10,799,521	Scenario 1a (required)	0
Scenario 1b (required)	4,299,547	Scenario 1b (required)	37,075
NIA Industry base case	8,577,606	NIA Industry base case	278,403
NIA Industry Accelerated LI	11,067,360	NIA Industry Accelerated SW	596,482
Cavity wall insulation	**Total**	**Internal wall insulation**	**Total**
Scenario 1a (required)	2,270,322	Scenario 1a (required)	0
Scenario 1b (required)	3,341,437	Scenario 1b (required)	1,489,696
NIA Industry base case	6,812,375	NIA Industry base case	915,861
NIA Industry Accelerated CWI	7,604,368	NIA Industry Accelerated SW	1,690,986

Table 14: Potential for LZC technologies by 2020 in England

Measure	**CERT and LCBP per year**	**Scenario 1b Yearly difference in installation rates**	**Increase required (multiples)**
Ground source heat pumps	7,946	-369,920	48
ASHP	0	-778	n/a
Biomass boilers	8,445	7,593	n/a
Solar PV	900	-91,243	102
Solar water heating	12,522	-113,962	10

57 Roberts, White, et al. (2007).

10.3 What employment would be generated in England?

Table 15: Employment generated in England under the three scenarios, shows how many full time equivalent (FTE) jobs would be created under each scenario, compared to the current number of FTEs for each measure. Scenario 1a results in the creation of 2,252 FTE jobs, each adding just over £26,000 of GVA. Scenario 1b results in the creation of 52,432 FTE jobs, with each adding slightly less GVA than in scenario 1a. The reason that the number of FTE jobs created in scenario 1b is so much higher is the inclusion of almost five million ground source heat pump installations. Each of these takes longer to install than any other LZC technology included. Although scenario 2 includes four million ground source heat pump installations, the longer timescale to 2050 instead of 2020 means that fewer need to be installed each year, so not so many installers are required. Scenario 2 therefore results in the creation of 7,499 FTE jobs. GVA per FTE is higher in this scenario because there is increased use of technologies for which a higher percentage of the cost is converted into GVA.

10.4 Other measures

The *How low?* study has explored the potential savings from applying all cost-effective measures possible to the UK housing stock. The modelling has shown that savings of 22%-36% are achievable by 2020 from cost-effective measures. If the more progressive option under scenario 1b is followed, this would set us on track for cuts of 80% by 2050 from all measures – including measures such as further decarbonisation of the power sector which, although not included in the modelled cut, would account for about one third of the carbon reductions by 2050. There are additional measures and delivery vehicles that have not been modelled in this study; the two key additional measures that have not been analysed are discussed here.

Table 15: Employment generated in England under the three scenarios

Scenario	2006 installers* (FTE)	2006 ancillary* staff (FTE)	2006 total staff (FTE)	Total staff – scenario (FTE/year)	Required increase in FTE	GVA /FTE
Scenario 1a (2020)	7,916	5,277	13,193	15,445	2,252	£26,124
Scenario 1b (2020)	9,526	6,350	15,876	68,309	52,432	£25,703
Scenario 2 (2050)	9,529	6,352	15,881	23,380	7,499	£37,550

10.4.1 Large-scale or community District Heating and CHP

District Heating and CHP are both technologies that can achieve cost-effective carbon savings. There are many large-scale industrial heat users that could benefit significantly from the implementation of CHP. The inclusion of 3MW+ heat users in the second phase of the EU Emissions Trading Scheme (EU ETS) should further the economic case for CHP by assigning a value to carbon in these instances.

The *How low?* study deals with the feasibility of installing CHP and DH in existing housing stock. Our literature review has found that its success is largely dependent on local circumstances and the organisation leading the development. There are a number of circumstances where CHP or district heating may be suitable to retrofit housing, including:

- housing only;
- housing and public sector buildings, such as hospitals and schools;
- housing and large business heat and power users; and
- housing, public sector buildings and businesses.

The most cost-effective schemes are often large-scale. The International Energy Agency (IEA) performed a comparison of distributed CHP/DH with large-scale CHP/DH. It concluded that a city-wide DH system supplied by a large combined cycle gas turbine (CCGT) power station would be most effective from a cost and carbon perspective. However, such a scheme would require significant investment and strong local political leadership.

London is the only region in the UK that boasts such strong leadership and is therefore currently best placed to deliver a large-scale or borough wide scheme. The London Energy Partnership commissioned Sustainable Energy Action (SEA) and Renewable Energy in the Urban Environment (RENUE) to develop a 'stretch' target for the reduction of carbon emissions from buildings in London to 2026. The target reduction chosen was 27% of 2000 emissions from buildings.

SEA/RENUE produced five scenarios showing how this target could be reached in London's buildings sector. The large CHP option had the highest NPV and carbon savings. In this scenario it is assumed that 2,400MWe of large gas CHP would be installed by 2026. The report does not assess the feasibility of this scale of installed capacity, although it notes that current UK capacity is approximately 1,800MWe of installed CHP.

In reality, large-scale schemes are difficult to implement in the existing housing stock as the upfront capital costs of retrofitting a heat distribution system are high and there are additional risks associated with the long-term security of customers (see ESCOs) below.

An additional significant inhibiting factor on most potential CHP developments is the aspect of project management across a large number of separate businesses and residences. Local authorities or public bodies are often the only organisations that own or operate enough heat-load to make a sizeable CHP development financially viable and practical from a management perspective.

The current regulatory system and financial incentives therefore mean that the involvement of a local authority or housing association would be essential to implementing this type of scheme – i.e. a not-for-profit (NFP) organisation willing to take on the perceived risks of the development. For example, a hospital in Bath proved an excellent economic case for CHP, which was strengthened further by its inclusion in the EU ETS; however, the case was weakened by the inclusion of housing and other large heat users. In this instance, the hospital energy manager is unlikely to extend the system to the local housing without further incentive as this will add both cost and risk.

A third of the cut in carbon emissions in the residential sector by 2050 would come from the decarbonisation of the power sector.

Retrofitting CHP and district heating in the existing housing stock is likely to require leadership from an agency with a vested interested in the carbon or fuel cost savings achieved. If the agency is based locally and/or has an existing relationship with the householder, then securing a supply contract will be far more straightforward.

The Aberdeen Heat & Power Co[58] is an example of an arm's length management organisation (ALMO), specifically set up to facilitate the installation of CHP in four multi-storey blocks, totalling 19 storeys and 288 flats. The council-owned properties were precast concrete panel, cavity construction with electric storage heating. Residents were experiencing significant levels of fuel poverty and the council undertook a feasibility study to identify the most cost-effective method of alleviating fuel poverty. The study considered various heating options for externally insulated and un-insulated flats. Heat options included: individual storage heaters; a central gas boiler; and a gas CHP plant.

The CHP plant delivered a heat cost of £3.65 per week to each flat, which was only marginally higher than the cost for CHP and external cladding of £3.18. The additional £4.4 million cost of over-cladding was prohibitive considering the additional benefit, so the CHP-only system was chosen. The council's capital budget would not have been able to meet the £1.6 million capital cost of the project. An ALMO was therefore set up to coordinate loan and grant financing with the council making yearly contributions of £215,000 until the loans are paid. While the driver for the project was fuel poverty, the CHP scheme provided the highest carbon savings of the heat only options, and the highest NPV of all options.

58 King (2007).

10.4.2 Energy Service Companies – ESCOs

Energy services include a wide range of activities, such as energy analysis and audits, energy management, project design and implementation, maintenance and operation, monitoring and evaluation of savings, property management, and equipment supply. The activities of Energy Services Companies (ESCOs) can be distinguished from those of other energy service provider companies in the following ways:

1 they guarantee the energy savings and/or the provision of the same level of energy service at a lower cost;
2 their remuneration is directly tied to the energy savings achieved; and
3 they can finance or assist in arranging financing for the operation of an energy system by providing a savings guarantee.

ESCOs are a potential delivery mechanism rather than a measure themselves. In theory they provide an ideal method of supporting the deployment of sustainable energy measures that are deemed cost-effective – i.e. that have a positive NPV with a discount rate of 3.5%. While more commonplace in the management of public authority buildings such as schools or hospitals where savings are achieved from lighting systems and boiler management controls, they are not widespread and have had little success in the residential sector.

The *Unlocking the Power House*[59] report examines barriers to the deployment of micro-generation technologies and the support mechanisms that may overcome them. The report identifies energy service companies as one mechanism of supporting their deployment. The 28-day rule was specifically identified by energy supply companies as a key barrier to the supply of energy services to residential customers.

The 28-day rule allowed residential energy customers to change energy supplier within 28 days of the last time they switched (Ofgem).

While the removal of this rule could enable energy companies to retain customers for longer by signing them up to long-term energy service contracts, in reality only 30% of consumers switch regularly, with 30% never having switched. The 28-day rule has recently been removed, meaning customers are free to switch irrespective of supply time. Despite this, energy supply companies remain in a similar position and could enter into energy service contracts with residential consumers if the correct legal framework were in place. In reality there is currently no incentive for them to provide energy services that would add cost and risk to their business model.

In practice, under the current regulatory framework, residential energy services companies are most likely to be provided by not-for-profit organisations. The Aberdeen Heat Company is a good example of an ESCO model that enabled the installation of high efficiency CHP, supplying both carbon savings and low cost power to residential consumers in high rise tenement blocks.

The business case for ESCOs could be significantly improved via the introduction of either a legally mandated cap and trade Supplier Obligation (see Policy gap analysis) or a system of Personal Carbon Allowances (PCAs). A cap and trade Supplier Obligation, as strongly supported by WWF[60], would encourage energy suppliers to reduce the emissions of their existing customer base and/or acquire low emissions customers. The provision of attractive energy services over a longer period of time would enable energy suppliers to both retain and acquire customers. In effect, this would provide a business model whereby energy suppliers would maximise profits by providing the least amount of energy necessary to the widest customer base.

Personal Carbon Allowances (PCAs) would provide an incentive for monitoring personal consumption of carbon and assign a value to carbon in the public realm. The need to both monitor and reduce a valuable commodity lends itself to Carbon Service Companies (CSCs) providing services to fuel rich households. It is important to note that a system of PCAs and a cap and trade Supplier Obligation could not be implemented simultaneously as the emissions reductions would be double counted[61].

59 Watson, et al. (2006). 60 wwf.org.uk/filelibrary/pdf/response_defra_evid_so.pdf
61 Roberts and Thumim (2006).

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11 Policy gap analysis

11.1 Existing mechanisms

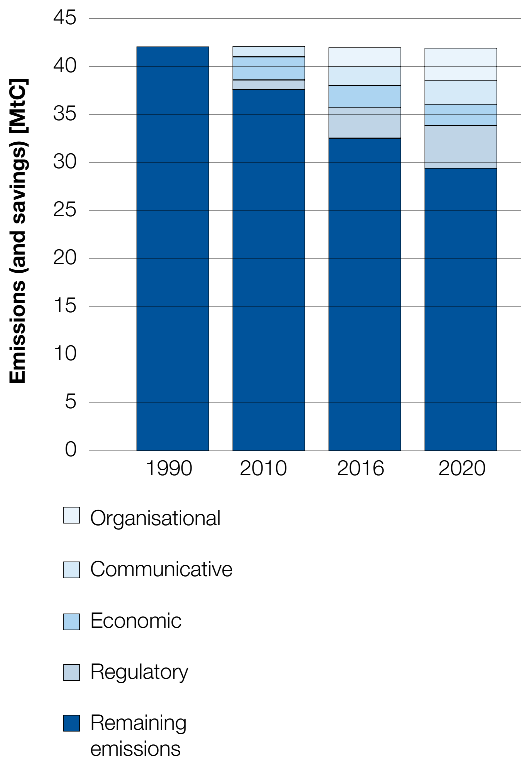
The UK government recognises the need for a package of policies to achieve carbon savings in the residential sector. Taken from Defra's UK Energy Efficiency Action Plan, Table 16 outlines the different types of policy instruments 'needed' to improve energy efficiency in, and reduce emissions from, housing. All – some UK-wide, some only at devolved nation level – are applicable to the existing UK housing stock.

This list reflects policies that are in place in the UK at present, and there appear to be examples of every 'needed' policy. However, a more systematic approach to the types of instruments[62] available to decision-makers reveals potential gaps, or opportunities. Table 17 presents a purely functional outline of different types of instruments, and cross-references these with relevant UK policies to 2020 (taken from the UK EEAP[63]). This makes it easy to identify the possible opportunities for instruments to deliver additional carbon savings (highlighted in blue in table 17).

Table 16: Different policies needed to tackle barriers to energy efficiency

Instrument	What problem does it tackle?	Examples
Regulation	Hidden costs, irrational consumer behaviour, market failures, split incentives	Building and product standards
Grants and fiscal incentives	Hidden costs, savings not material, inertia and lack of consumer interest, split incentives – landlord/tenant	Warm Front and devolved nation variants, EEC subsidies, Reduced VAT, Low Carbon Buildings Programme
Information and awareness raising	Lack of awareness or wrong information about costs and benefits of energy efficiency	Energy Saving Trust activities, Product labelling, Energy Performance Certificates, Real-time Displays, CO_2 Calculator, 'Act on CO_2' campaign, Climate Challenge Fund projects
Voluntary agreements	Slow implementation of regulation	Appliance manufacturers and retailers
Public sector leadership	Public need for leadership and sense that government takes the issue seriously	Public sector carbon and energy efficiency targets
R&D – innovation	Need for new products – new applications or improved efficiency	Development of LED lighting, vacuum panel refrigeration, solid wall insulation, etc.

Figure 9: Impact of UK policy framework on CO_2 emissions from the residential sector to 2020



62 Klinckenberg and Sunikka (2006).
63 Some apply to the UK as a whole, some to just one or more devolved nations.

Table 17: Possible instruments compared with relevant UK instruments to 2020

Type	Instruments	Relevant UK-wide instruments to 2020	Proposed UK instruments to 2020
Regulatory	Regulatory benefits for above-minimum energy performance Minimum energy performance requirements Product phase-outs and quotas **Energy performance improvement requirements for refurbishment** **Minimum energy standards at point of sale**	Building Regulations (England & Wales 2002, 2006; Scotland 2007), Building a Greener Future – Towards zero carbon homes*[64] (includes Code for Sustainable Homes), improved enforcement of the Building Regulations, phase-out of incandescant bulbs	Introducing phased minimum standards for homes[65] at point of resale – e.g. no G-rated property can be re-sold after 2010, no F-rated after 2013 and no E-rated ones after 2016
Economic	Tax relief Subsidies Product tax Energy/**carbon tax** Energy export/**block tariffs** **performance improvements**	EEC-1, EEC-2, CERT, NI Energy Efficiency Levy, Northern Ireland Environment and Renewable Energy Fund (NI EREF), Fuel Poverty Schemes (Warm Front and Devolved Administration variants), Green Landlord Scheme, reduced VAT rates[66], Low Carbon Buildings Programme, Stamp Duty exemptions for zero carbon homes, Scottish Communities and Householder Renewables Initiative	Extending landlord scheme to corporate (not just private) landlords, tariffs for exported electricity
Communicative	Building energy audits R&D and demonstration projects Voluntary energy conservation/carbon saving agreements Consumer advice and promotion Product labelling	Energy Performance of Buildings Directive (Energy Performance Certificates), metering and billing, Market Transformation Programme (promotion of voluntary product standards), Climate Change Communications Initiative (and Devolved Administration counterparts), Energy Saving Trust advice and promotion activities, appliance energy labelling	Series of demonstration projects
Organisational/ framework	Independent energy audits Professional management for multi-family housing Energy service contracts Public sector leadership Training and accreditation schemes **Personal carbon allowances**	Major targets, Supplier Obligation, Planning Policy Statement on Planning and Climate Change, Scottish Planning Policy 6 on Renewable Energy, accreditation of microgeneration technologies (products and installers) Ministerial Interim Planning Policy Statement, Wales	

The impact of the current policy framework on UK residential emissions outlined by the government to 2020 is illustrated in Figure 9.

64 Consultation paper – representative of aim for all new homes to be zero carbon (CLG, 2007). 65 Boardman (2007). 66 Covering all (professional installation of) insulation, draught stripping, hot water and central heating controls; solar panels, wind and water turbines, ground-source and air-source heat pumps and micro-CHP; wood-fuelled boilers.

Table 18: Potential mechanisms – in the pipeline and beyond

Type	In the pipeline from Europe to the UK (prior to 2020)	Further proposals (including post-2020) – UK wide)
Regulatory	Significant lowering of the threshold (below 1,000 sq m) at which minimum energy performance requirements must be applied to buildings undergoing major renovations	Remove the threshold for major renovations to capture all dwellings
Economic	EU minimum standards for energy performance of components (e.g. windows, passive heating/cooling) EU minimum efficiency requirements for electricity/heating/cooling plant smaller than 20MW (includes district heating and micro-CHP) EU plans to expand lowered rates of VAT on energy efficient appliances and equipment	Extend lowered rates of VAT to all 'Energy Saving Recom-mended' appliances and equipment, including for DIY Introduce Stamp Duty and council tax rebates linked to Energy Performance Certificate recommendations Develop and implement home refurbishment low-interest loans, contingent on refurbishment incorporating low-carbon Introduce block tariffs on the back of smart meters Full public consultation and debate on personal carbon allowances/carbon tax from 2011, with a view to introducing either from 2020
Communicative	EU development of teaching aids to be included in primary, secondary and vocational educational curricula EU proposals for more detailed metering and billing requirements	Mandate the rollout of smart energy meters[67] with an agreed industry standard for connectivity to energy displays
Organisational/ framework	Possibility of an EU-wide white certification scheme EU Commission will seek to identify and remove legal barriers to ESCOs	Full public consultation and debate on personal carbon allowances/carbon tax from 2011, with a view to introducing either from 2020

11.2 Potential mechanisms

Just because there is a gap in policy types available does not mean they are necessary in the UK's policy mix. However, given the scale of what might have to be achieved by 2020 and 2050, all available tools need to be considered. The most significant omissions from the UK's current and future policy mix are financial (as opposed to fiscal) instruments – a subset of 'economic' instruments. The post-2011 Supplier Obligation has been categorised as an 'organisational/framework' instrument because energy suppliers are likely to have the flexibility to implement their own choice of 'economic' and 'communicative' instruments to achieve their obligations – as they currently have under the Energy Efficiency Commitment.

Table 18 outlines policies that go beyond what is stated in the UK Energy Efficiency Action Plan, based in the first instance on what is in the pipeline following the European Commission's 'Action Plan on Energy Efficiency', and what further mechanisms are necessary to minimise emissions from housing.

67 'Smart' meters are broadly defined by their ability to provide real-time and historical energy consumption and cost information, to both households and energy suppliers (two-way). Energy displays, additionally, provide the information in a more accessible and interactive form.

11.3 Deployment strategy – key supporting mechanisms

The review of existing literature and research findings has uncovered a number of key mechanisms that may have a direct influence on or benefit to the implementation of the measures here. The mechanisms and the timeframe associated with them have been summarised here.

11.3.1 Low interest loans for energy (German model) – 2008-20 Measures – Scenario 1b measures

Borrowers are able to take out low interest loans for measures that help older properties reach new-build standard through refurbishment (only pre-1984 dwellings are eligible for the loans scheme). Upon reaching this standard, the government will repay 10% of the loan to the householder. Prior to 1 June 2006, the government repaid 15% for meeting this condition. The contribution fell from 15% to 10% because of the rapid update and the increase in people reaching new-build standard with their refurbishments. In other words, this has been a huge success, with solely voluntary take-up at present.

Up-to-date features of the loans include:

- a fixed (and heavily subsidised) interest rate for 10 years – the rate varies depending on the loan amount and duration, and is revised annually;
- repayment over 4 to 30 years;
- up to €50,000 per dwelling, regardless of which package (see below) is chosen;
- loans can cover 100% of the investment, as well as labour cost and secondary costs, such as scaffolding;
- flexible repayment (increasing repayments incurs no additional cost);
- can be used in combination with other (non-energy) refurbishment loans – for example, additional subsidised finance can be used for including added individual measures (the CO_2 refurbishment programme can only finance packages of measures, see below); and
- ESCOs carrying out refurbishments are eligible for the loan.

Furthermore, the programme takes a 'whole house' view. To be eligible for finance, refurbishments must achieve a reduction in CO_2 emissions of 40kg/m2/year. This is to be achieved through one of five packages of measures on offer. Packages 1 to 4 are different combinations of: loft insulation, wall insulation, basement ceiling/ground floor insulation, window 'renewal', heating 'renewal', and fuel switching. These packages can be applied to most dwellings, and are 'guaranteed' to achieve the required reduction if fully applicable. Package 5 is designed for unusual cases or buildings that already have some measures installed, and is more tailor-made. Under package 5, a certified expert will help determine the measures necessary for achieving the emissions reduction.

Widespread council tax rebates would provide a simple opportunity to reward sustainable actions, and help change the perception that environmental action is somehow 'painful'.

11.3.2 Fiscal Incentives – 2008 onwards Measures – Scenario 1a and 1b

It is vital that the government employs a suite of economic instruments to encourage the development of more energy efficient homes (and sustainable homes more widely). In particular the report recommends the Government reduces the rate of VAT on energy efficiency measures, introduces stamp duty rebates (which could be easily linked to the deployment of minimum standards at point of sale, as set out in 11.3.3), provides a nationwide council tax rebate system and ensures that the appropriate grant funding for fuel poverty measures (Warm Front) and LZC (Low Carbon Buildings Programme) are sustained and increased in line with the identified need.

Value Added Tax (VAT)

The rate of VAT on energy efficiency measures should be reduced, to perhaps 5 per cent, on; the supply and installation of energy efficient products or materials; DIY energy saving materials bought by householders; and the most energy efficient equipment, i.e. appliances and products. In terms of the equipment and appliances that could be covered by reduced VAT, the report team suggests the inclusion of energy efficient products such as micro-CHP, lights, insulation and appliances[68].

68 Defined as A-rated / Energy Saving Recommended (ESR)

Stamp duty rebates

There should be a differential stamp duty to incentivise improved energy efficiency of housing at point of sale (see minimum standards at point of sale). In order to ensure that all homes could benefit from this policy recommendation, the team suggests reducing the rate of stamp duty for home owners who improve the energy performance rating (as defined by their Energy Performance Certificate) to a higher band, or perhaps a higher SAP rating within the band. The relative rate of the reduction could in turn be linked to the number of bands or points achieved.

Council Tax rebates

There has been a great deal of publicity about Local Authorities fining 'unsustainable' behaviour (such as failure to recycle, or raising parking fees), but hardly any about financially rewarding sustainable actions. Widespread council tax rebates would provide a simple opportunity to change this, and help change the perception that environmental action is somehow 'painful'[69]. This must be carefully aligned with further work into the social distribution of energy efficiency improvements. Despite the rebates, most environmental home improvements entail some level of capital expenditure by the home-owner/tenant, and it is essential not to restrict the assistance to the "able-to-pays". A much more sophisticated grant system than that presently utilised is required, as outlined below, to ensure the equity of installation and rebate.

Grant funding for sustainable energy measures

The Government is not on course to meet its statutory obligation to end fuel poverty in vulnerable households by 2010 and indeed there have been substantial increases in fuel poverty in all sectors. While the report team acknowledges that rising fuel prices have been the principal cause for this increase, the Government is planning to reduce the budget for Warm Front which is already lower than that recommended by the Fuel Poverty Advisory Group (FPAG)[70]. The successful rollout of all scenarios is dependent on deploying energy efficiency measures in all homes (including those of the fuel poor). Therefore, the Government should increase the budget for this work rather than decrease it. In addition to this, Government funding allocated to Warm Front and LCBP should be increased to support the deployment of far higher numbers of LZC technologies.

11.3.3 Minimum standards at point of sale – 2008-20

Measures – Scenario 1a measures only

The Oxford ECI *Home Truths* report recommends that all homes being sold should meet a minimum level of energy efficiency. The mechanism described below would support the implementation of scenario 1a by ensuring that all homes reach their cost-effective potential by 2020.

Taken from *Home Truths*:
"Energy Performance Certificates, which rate houses from A to G, are rolled out for every home in the UK (not just those being sold or let) from 1 January 2008. A minimum standard is set and progressively tightened to transform the housing sector by making it illegal to re-sell (or let) the most energy-inefficient houses. Houses in bands F and G have such low levels of thermal comfort they are officially a health hazard – there are three million such homes in the UK today. They have to be improved before they can be re-sold. No G-rated property can be re-sold after 2010, no F-rated after 2013 and no E-rated ones after 2016."

It's the report team's understanding that an F-rating could be achieved with relative ease through the installation of low energy light bulbs, loft insulation and modern condensing boilers. For cavity walled properties, flats and mid-terrace solid walled properties an E-rating could again easily be achieved through the implementation of these measures. The 'minimum standards' at point of sale policy therefore seems a relatively straightforward method, at low cost to the government, of the implementing the measures in scenario 1a.

11.3.4 Reform the energy market – 2008-50

Measures – All LZC technologies

Reform the energy market: A feed-in tariff is adopted for electricity generated by LZCs, guaranteeing a premium price for exported electricity that reflects the true cost of installing the equipment. This is a recognised method of encouraging the installation of electricity from micro-generation, which has been an effective measure in Germany and Spain[71]. In Germany (perhaps the most effective system, developed and supported politically since 1990), feed-in tariffs have helped them become a world leader in renewable energy. It is estimated that the policy has generated in the region of a quarter of a million jobs, and saves around 100 million tonnes of CO_2 annually, at the cost of around EUR1.80 per household, per month.

69 British Gas worked first with Braintree council and has extended the scheme to 60-plus councils to offer council tax rebates to people who install energy efficiency measures. Each household who invests in home insulation from British Gas under this scheme will receive a rebate of up to £100 from their local authority and could see energy savings of around £200 a year through installing loft and cavity wall insulation. http://www.britishgas.co.uk/energy-efficiency/products/home-insulation/council-tax.html 70 FPAG Fifth Annual Report 2007
71 Mendonça (2007).

A renewable heat obligation should be introduced requiring a proportion of household heat to come from LZC sources. It would be complemented by a properly delineated and monitored green gas tariff. Energy tariffs are reformed so that they reward energy saving rather than high consumption.

11.3.5 Supplier Obligation – 2011-20 Measures – Most likely those under scenario 1b

The Supplier Obligation (SO) is the successor to the Carbon Reduction Commitment (which itself is the successor to the current Energy Efficiency Commitment), and will start in 2011. The government is currently looking at possible designs for the SO.

A recent (August 2007) study by Centre for Sustainable Energy, in response to the government's call for evidence as part of the process of designing the SO, examined the social impacts relating to a cap-and-trade supplier obligation. Such a supplier obligation would potentially create far more significant changes in energy supplier practices compared with the possible alternative of a further development of a measures-based approach, as characterised by the Energy Efficiency Commitment (EEC) and forthcoming Carbon Emission Reduction Target (CERT). Not least among these changes is that suppliers would be required to reduce the carbon emissions of only their *own* customers; measures-based approaches have not, to date, featured this focus.

11.3.6 Personal Carbon Trading (PCT)/carbon taxes – 2015/20 to 2050 Measures – Unknown, dependent on the public's personal opportunity and willingness to act

Personal Carbon Trading (PCT) is potentially a very effective, fiscally progressive measure for carbon reduction in the household sector, but further research is needed into the likely equity and distributional impacts of such a system, and its technical feasibility, before public acceptability is tested. Under a system of PCT a trusted agency or body would set the overall cap for emissions with the size of the cap defining the carbon saving achieved.

A possible outcome of PCT would be that richer households, which tend to be high carbon emitters, will seek measures to reduce carbon emissions from their household energy use, or buy carbon allowances from others. Those with carbon allowances to sell are likely to be less well-off households, who may then use the money they gain from selling allowances to take measures to reduce their energy use, freeing up more carbon allowances for them to sell in the future.

Carbon taxes are a more regressive[72] measure which are easier to administer than a system of PCT. However, their ability to reduce carbon emissions is dependent upon the elasticity of the market place – i.e. the rate at which the change in cost is translated to a change in demand. The price of cigarettes is an excellent example of a commodity where increasing price has had little effect on demand, which is of course in part linked to the end users' nicotine addiction. It could be argued that we are addicted to oil, with petrol prices now equalling the highest point in the 1970s. These prices have not resulted in a wholesale change in end-user transport behaviour, such as increased cycling or public transport use, so why would one assume carbon taxes would do so in the future.

Prior to the introduction of either carbon taxes or PCTs, the government must seek a better understanding of the distribution of emissions by household; those households that stand to lose and gain; and the opportunities that these households have to reduce their emissions. The impact of PCTs depends upon the cap placed on total emissions and the associated share distributed to the public. It is likely that the first five years of a PCT scheme would cut the 'carbon fat' – or the wastage that can easily be trimmed by simple behavioural changes and consumer purchasing decisions.

11.4 Overview

The *How Low?* report joins a growing body of research that demonstrates an 80% cut by 2050 is feasible with negligible impact on the UK economy. The IPPR, RSPB, WWF report, 80% Challenge: *Delivering a low-carbon UK* and the Oxford ECI *Home Truths* report both agree that the residential sector can meet this target, with the *80% Challenge* study recommending further savings to offset growth in other sectors. While these studies don't necessarily agree on the platter

72 See http://en.wikipedia.org/wiki/Regressive_tax (Wikipedia, 2007).

of measures required to achieve the 80% cut, they suggest that the most cost-effective sustainable energy measures must be applied to the residential sector first – preferably by 2020. It will be required to deliver savings in all sectors, but the residential sector is an early and strong priority.

The government's 2007 budget presented the aim that: 'by the end of the next decade, all householders will have been offered help to introduce energy efficient measures with the aim that, where practicably possible, all homes will have achieved their cost-effective energy efficiency potential'. The *How Low?* study examined the potential carbon reductions from the residential sector based on the government's own definition of cost-effectiveness and our own more meaningful definition looking at lifetime benefits of measures. However, a strict interpretation of government policy would indicate that a cost for carbon must be incorporated into this cost-effective definition for policy decision-making.

Scenario 1a, based on the government's definition, achieved a 9.3MtC reduction (33.1 MtC total emissions), which falls short of both the National Energy Efficiency Action Plan (NEEAP) and Climate Change Bill targets (apportioned to the housing sector) of 29.3 and 28.8-31.4MtC respectively.

Our more meaningful definition of cost-effective, scenario 1b, exceeded both these targets, achieving a 14.7MtC reduction. This conclusion concurs with the findings of the recent BRE study *Delivering cost-effective carbon savings to existing homes by 2020,* which showed there is significant potential for savings from solid wall insulation, efficient glazing, floor insulation and renewable generation technologies between now and 2020.

Scenario 1b relies on the deployment of significant numbers of solid wall insulation and LZC technologies. If the government is to only achieve the savings associated with Scenario 1a by 2020, it must still ensure that significant numbers of insulation and heating measures are implemented. However, these savings are dependent on householders taking these measures when they are offered them, which will require them to have a vested interest in taking those measures; a better understanding of their own energy use and carbon emissions; and more engaging and creative marketing techniques.

The 80% reduction in residential emissions by 2050 is achievable under scenario 2b. This requires the implementation of the modelled sustainable energy improvements, projected improvements in the efficiency of appliances, the decarbonisation of electricity, green gas, and a 20% improvement in energy use behaviour. In order to implement scenario 2b by 2050, we will need to first implement scenario 1b by 2020.

In February 2007, the IPCC released a summary of the forthcoming Fourth Assessment Report. According to this summary, the Fourth Assessment Report finds that human actions are "very likely" to be the cause of global warming, meaning a 90% or greater probability[73]. There is consensus among the scientific community that an 80% reduction in residential carbon emissions by 2050 is possible.

It is clear that we need to act now if we are to meet this 2050 target, which will require the government to introduce strong supporting policies and provide further financial support for sustainable energy measures. The £2.6-£3.5 billion per year required to deliver the residential sector measures in Scenario 2b is minimal compared to the cost of doing nothing. The Stern Review[74] estimated the cost to the economy of mitigating the harmful impacts of climate change to be 10 times that of acting now. For scenario 2b, the total benefit per £1 invested is less than £1, but if the cost of LZC technologies falls in line with RAB predictions, total cost will fall by approximately £43 billion to under £113 billion, giving savings per £1 invested of between £0.99 and £1.05. In this instance the economic benefit therefore matches the investment made.

The findings of this study provide a further imperative for the government to introduce a framework of policies and mechanisms that ensure these measures are implemented. The introduction of further funding through direct subsidy such as LCBP, or regulation such as CERT, will not necessarily ensure that this implementation occurs. The public needs to have a stake in the implementation of these measures in their own homes, which will require the measures to deliver tangible benefits – for example, increasing the value of their property or saving tradable/taxable carbon emissions.

73 http://news.bbc.co.uk/1/hi/sci/tech/6321351.stm
74 Stern (2007).

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12 Annex I – Model criteria

12.1 Overriding scenario criteria

- Scenario 1a – The 'cost-effective measures' selected were defined by Gordon Brown, as then Chancellor, in the 2007 Budget statement.
- Scenario 1b – These measures were deemed cost-effective by the report team's analysis of measures, and packages thereof, that have a positive NPV (see Annex II).
- Scenario 2 – This scenario included all measures.

The platter of measures applied under each scenario was then subjected to the following criteria that limit their application to suitable sites and ensure that the most pragmatic measures are applied.

12.2 General criteria

- Where they can be fitted, low cost insulation measures such as draught-proofing, loft insulation and cavity wall insulation (plus cfls – low energy light bulbs) are fitted in preference to all other measures.
- Where property is in a gas supply area, a gas condensing boiler is next selected if the above insulation measures fail to provide the required saving.
- Where the property is off-gas, an oil condensing boiler is generally selected as the next most appropriate measure.
- An LPG condensing boiler may be next selected where there is already an existing LPG boiler and bulk storage tank and the property is off-gas.
- Renewable energy measures are applied only where the above heating and insulation measures fail to provide the required saving.
- Heating measures are only selected without insulation measures where the dwelling already has a satisfactory existing level of draught-proofing, loft insulation and cavity wall insulation.
- In solid wall dwellings, condensing boilers alone can be installed if there is no external or internal insulation, provided the other elements are insulated to a satisfactory standard.
- Ground or air source heat pumps are only installed where the dwellings are fully insulated, including solid wall insulation.

12.3 Specific criteria for insulation measures

- Draught stripping is confined to single glazed windows and doors.
- Double glazing is confined to single glazed windows and doors.
- Existing draught-proofed and double glazed windows are considered to be already satisfactorily draught-proofed, but double glazing can be installed to replace fully draught-proof single glazing.
- Loft insulation is only installed in houses and not flats. (The latter includes top floor flats as the Fuel Prophet model does not provide energy savings from LI for these.)
- Insulation for flat roofs is assumed to give the same savings as LI but to cost three times as much to install.
- Loft insulation, including top-up insulation, is limited to dwellings that have existing loft insulation of below 125mm.
- Existing loft insulation greater than 125mm is considered to be already satisfactory.
- All totally un-insulated cavity walls are assumed to be suitable for cavity insulation, unless in a severely exposed location.
- External wall insulation is not selected for listed buildings with solid walls or homes in a conservation area.
- Internal wall insulation is not selected for individually listed buildings with solid walls and/or where the habitable rooms are already small.

12.4 Specific criteria for heating measures

- A condensing boiler is not selected where the existing boiler is a condensing or combi boiler or CHP system and less than five years old.
- A condensing boiler is not selected where the existing boiler is another type and less than three years old.
- Boilers of less than three and five years old can be replaced if another fuel and/or heating system is required.
- Oil and LPG-fired heating is only upgraded using the same fuel in off-gas areas.
- Ground source heat pumps are only selected for houses and bungalows (not flats) and where the garden is 25 metres in depth or larger.
- Air source heat pumps are only selected where the total floor area of the house, bungalow or flat is less than 60 square metres.
- Biomass boilers are not selected where the area has gas, for flats, or where the youngest occupant is aged 60 years or over .
- Solar hot water (SHW) installations are not selected for flats or houses/bungalows with flat roofs or for any dwellings that are listed or in a conservation area. The model also limits the application to a representative number of south-oriented roof spaces.

The Fuel Prophet model does not record the separate savings or installation cost of improved heating controls, but allows for modern heating controls in the savings and installation costs given for new heating appliances. The latter are thereby included in the model wherever a new heating boiler/system is installed. Similarly, the new AFP does not include hot water tank insulation, but again this is covered where new heating is installed, for example by using a condensing combi boiler.

12.5 Specific criteria for electricity generation measures

- Solar photovoltaics are not selected for flats or houses/bungalows with flat roofs or for any dwellings that are listed or in a conservation area. The model also limits the application to a representative number of south-oriented roof spaces.
- The model has applied a 6kW Proven and an Ampair 600 to the housing stock. The model limits the application to exposed sites with sufficient numbers of storeys (dependent upon exposure).

12.6 Criteria for GVA assumed

Measure	GVA
Cavity wall insulation	40%
Loft insulation	25%
Hot water tank insulation	5%
Draught proofing	10%
External wall insulation	25%
Internal wall insulation	25%
Replacement boilers	30%
Central heating systems	30%
Oil central heating and replacement	30%
Ground source heat pumps	30%
ASHP	30%
Biomass boilers	30%
Solar water heating	30%
Micro-CHP	30%
Solar PV	30%
Micro wind	30%

Annex II
– Packages of measures by scenario

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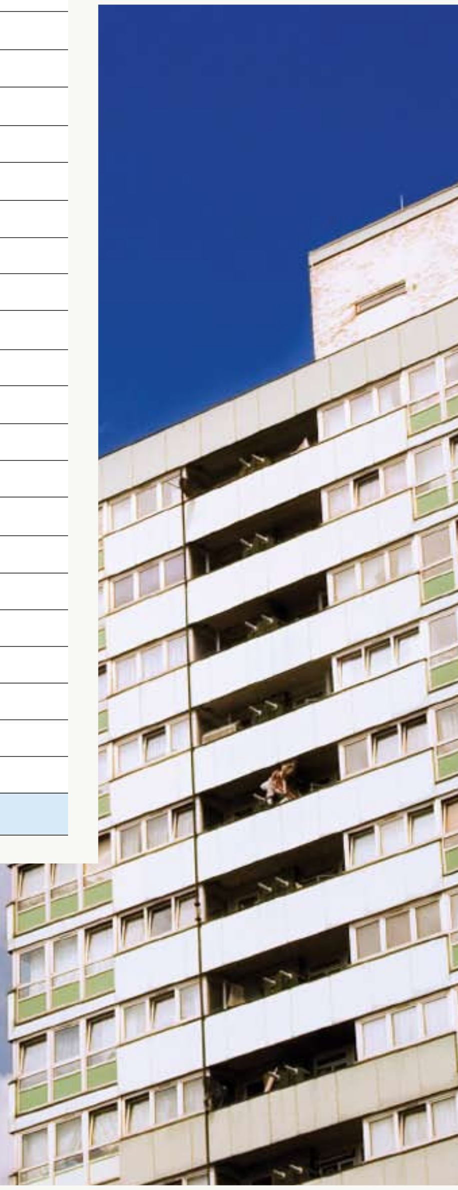
Single insulation measures and low energy lighting	
cfl	compact fluorescent lights
dp	draught proofing
cwi	cavity wall insulation
li	270mm loft insulation
iwi	internal wall insulation
dg	double glazing
wri	wall reform insulation
ewi	external wall insulation
Insulation packages	
insl	insulation package with LI only
insc	insulation package with cavity insulation
insi	insulation package with internal wall insulation
insw	insulation package with wall reform insulation
inse	insulation package with external wall insulation
Heating measures	
gcb	gas condensing boiler
chp	micro-chp
ashp	air source heat pump
bio	biomass boiler
ocb	oil condensing boiler
gshp	ground source heat pump
Pcb	LPG condensing boiler
Renewables	
SHW	solar hot water
MWT	micro wind turbine
SPV	solar photovoltaic

Packages of measures installed in England under Scenario 1a

Packages*		Av. SAP ratings before	after	Average cost (£)	Total cost (£)	Households number	percent
1	cfls only	52.2	54.2	27	31,580,000	1,180,052	5.6
2	dp only	46.0	48.7	229	2,842,000	12,395	0.1
3	dp + cfls	46.0	50.0	294	549,423,000	1,868,190	8.9
4	cwi only	53.8	72.4	156	45,613,000	291,728	1.4
5	li only	50.6	53.8	349	1,372,121,000	3,933,813	18.8
6	insl	18.9	23.6	311	101,166,000	325,249	1.6
7	li + cwi	50.8	59.6	444	1,494,000	3,369	0.0
8	insc	49.7	70.2	365	410,363,000	1,122,924	5.4
17	gcb only	56.8	73.0	1,570	359,078,000	228,783	1.1
18	insl + gcb	47.0	60.5	1,380	6,136,516,000	4,447,953	21.3
19	insc + gcb	63.5	94.7	1,474	9,045,943,000	6,135,024	29.3
31	ocb	37.7	50.1	1,533	6,796,000	4,433	0.0
36	insl + ocb	31.7	45.8	1,012	406,627,000	401,781	1.9
38	insc + ocb	48.7	73.4	935	878,574,000	939,731	4.5
117	pcb only	25.8	43.0	1,301	15,613,000	12,003	0.1
118	insl + pcb	17.2	46.9	1,342	17,468,000	13,013	0.1
119	insc + pcb	25.8	84.3	1,659	17,689,000	10,664	0.1
Total packages		52.4	68.5	927	19,398,907,000	20,931,105	100.0

Packages of measures installed in England under Scenario 1b

Packages*		Av. SAP ratings before	after	Average cost (£)	Total cost (£ x 1,000)	Households number	percent
8	insc	53.5	81.2	550	382,491	695,493	3.3
8.2	insc + SPV	39.8	55.4	6,900	1,732,078	251,019	1.2
10	cwi dg	35.0	68.9	2,342	35,485	15,150	0.1
12	insi	58.9	92.0	801	31,635	39,485	0.2
12.2	insi + SPV	43.7	73.8	7,869	5,164,816	656,390	3.1
15	insc + SHW	43.3	90.9	2,870	458,739	159,819	0.8
16	li cwi dg	26.5	70.4	6,192	397,155	64,143	0.3
17	ccb	34.1	45.3	4,167	142,634	34,231	0.2
18	insl + gcb	30.3	48.6	3,431	111,774	32,581	0.2
19	insc + gcb	53.1	92.9	1,823	5,946,094	3,260,895	15.6
21	chp	60.0	69.1	2,679	23,671,264	8,834,288	42.2
21.2	chp + SPV	33.7	58.6	11,253	162,982	14,484	0.1
22	insi + SHW	19.7	81.8	3,564	86,784	24,352	0.1
23	insw	44.6	90.1	4,594	17,500	3,809	0.0
24	ashp	38.7	112.5	3,000	5,796	1,932	0.0
27	insc+chp	46.7	60.7	3,348	190,427	56,884	0.3
29	insl+bio	43.1	71.3	4,697	49,357	10,508	0.1
32	insi+ccb	44.7	90.8	2,573	4,398,490	1,709,548	8.2
32.2	insi+gcb+SPV	35.7	93.5	10,334	30,569	2,958	0.0
37	insc+gcb+SHW	38.7	107.2	6,353	323,567	50,935	0.2
42	gshp	48.2	120.0	5,616	18,363,261	3,269,739	15.6
42.2	gshp + SPV	37.0	120.0	12,591	3,126,863	248,335	1.2
51.2	insc+gshp+SPV	21.9	38.5	10,548	53,328	5,056	0.0
52	inse	13.6	47.0	2,827	80,267	28,397	0.1
53	insl+ashp+SHW	25.9	120.0	8,248	67,461	8,179	0.0
57	insi+ocb	4.1	34.4	6,438	4,294	667	0.0
57.2	insi+ocb+SPV	46.3	76.6	10,651	100,561	9,441	0.0
65	gshp + SHW	37.1	120	8,674	11,899,198	1,371,882	6.6
66.2	insi+gshp+SPV	14.6	97.1	13,626	68,754	5,046	0.0
72	insc+gshp+SHW	19.1	108.8	10,477	14,165	1,352	0.0
80	insi+gshp+SHW	1.0	92.0	10,295	22,669	2,202	0.0
88	inse+ocb	16.8	79.3	10,543	400,492	37,985	0.2
91.2	inse+gshp+SPV	53.4	120.0	12,049	8,543	709	0.0
95	inse+gshp+SHW	34.0	115.6	12,221	102,738	8,407	0.0
119	ins+pcb	25.9	75.8	1,884	13,949	7,404	0.0
132	insi+pcb	16.1	100.6	2,726	20,170	7,400	0.0
Total packages		52.4	91.0	3,712	77,686,350	20,931,105	100.0



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14 Annex III – Current installation rates and economic statistics for key measures, England

Measure	Total measures	Labour/ job (days) [1]	Installer (FTE) [2]	Plus ancillary staff [3,4]	Installed cost/ measure [5]	Installed cost/ measure [5]	Total costs	GVA	GVA/FTE
Cavity wall insulation	378,052	0.4	859	1,432	300	£113,415,497	£45,366,199	£45,366,199	£52,800
Loft insulation	490,188	0.25	696	1,160	262	£128,429,202	£32,107,301	£32,107,301	£46,112
Draught proofing	245,080	0.3	418	696	200	£49,015,996	£4,901,600	£4,901,600	£11,733
External wall insulation	16,802	15	1,432	2,387	8000	£134,418,366	£33,604,592	£33,604,592	£23,467
Internal wall insulation	3,360	6	115	191	2000	£6,720,918	£1,680,230	£1,680,230	£14,667
Gas central heating and replacement	920,774	1	5,232	8,719	1200	£1,104,928,815	£331,478,645	£331,478,645	£63,360
Central heating systems	389,805	3	6,644	11,074	3700	£1,442,278,715	£432,683,615	£432,683,615	£65,120
Oil central heating and replacement	62,589	2	711	1,185	5367	£335,891,895	£100,767,568	£100,767,568	£141,680
Ground source heat pumps	105	13	8	13	5100	£536,400	£160,920	£160,920	£20,714
ASHP	50	3.5	1	2	3000	£150,000	£45,000	£45,000	£45,257
Biomass boilers	44	8	2	3	6000	£266,824	£80,047	£80,047	£39,600
Solar PV	340	4	8	13	6500	£2,206,941	£662,082	£662,082	£85,800
Solar water heating	1,320	6	45	75	2500	£3,300,000	£990,000	£990,000	£22,000
Wind turbine	243	2	3	5	4000	£971,294	£291,388	£291,388	£105,600
Total	2,508,509		16,171	26,951		£3,321,559,569	£984,527,797	£984,527,797	£632,310

Annex IV
– Summary of modelled savings for devolved nations

Modelled carbon savings (MtC) for England with imputed totals for the devolved nations and the UK

	1990 emissions	2004 emissions	Scenario 1a	Scenario 1b	Scenario 2 (modelled)*
UK (inc new homes)	42.4	41.7	6.2	9.5	11.6
UK	42.4	41.7	8.1	11.4	13.1
England		34.9	6.7	10.0	11.0
Wales		2.2	0.5	0.3	0.5
Scotland		3.9	0.8	0.9	1.3
Northern Ireland		0.8	0.1	0.2	0.3

* Doesn't include decarbonisation of electricity

Modelled percentage reductions in carbon emissions for each nation based on 2004[75] baseline

	Scenario 1a	Scenario 1b	Scenario 2 (modelled)*
UK	19.5%	27.4%	31.4%
England	19.2%	28.6%	31.6%
Wales	23.0%	15.9%	22.7%
Scotland	21.0%	23.0%	32.7%
Northern Ireland	15.2%	28.4%	40.3%

75 A 2004 baseline has been used here as the breakdown of UK emissions for 1990 are unknown.

Annex V
– Imputation methodology

16.1 Imputations for devolved nations – Scotland and Wales

In the full improvement model, the type of measure or package selected for each sample dwelling is governed mainly by the generic dwelling type, particularly the original heating fuel used, the wall construction and whether the dwelling is a house/bungalow or a flat. The selected measure or package is also defined by the fuel used after improvement. The extent of measures required is determined by the existing standard of heating and insulation in each dwelling prior to improvement.

The imputation is based on the assumption that dwellings in Scotland and Wales of the same generic type – i.e. with the same main heating fuel, wall construction, the same built form, and with the same level of energy efficiency as those in England – will require the same type of energy measures and generate the same savings and improvement costs.

For the imputation, the full list of 36 generic dwelling types has been reduced to 20. This has been achieved by combining non-traditional construction with solid walls, and by using just two built forms – houses/bungalows and flats – for dwellings heated by electricity, solid fuel, oil and LPG (which tend to be the least frequent generic types).

Each of these 20 generic dwelling types, however, has been broken down by the fuel used after improvement, and by the original level of energy efficiency. For the final fuel used, six categories are used: electricity, solid fuel, oil, LPG and gas, with the latter fuel being sub-divided into that used in a condensing boiler and that used in CHP systems. For the level of energy efficiency, five SAP bands are used – under 35; 35 to 45; 45 to 55; 55 to 65; and 65 or more – to reflect the existing standard of heating and insulation.

Like the English Housing Condition Survey (EHCS), both the Scottish Housing Condition Survey (SHCS) and Living in Wales (LIW) survey include the variables required to determine the generic dwelling type and SAP rating of each sample dwelling. However, as the fuel after improvement is unknown for Scotland and Wales, the address codes of the SHCS and LIW are used to randomly distribute the Scottish and Welsh samples to the same fuel or a new fuel, in the same proportions as those generated by the English improvement model. Including the use of gas CHP, up to five fuel switch categories are used for each existing fuel – for example, solid/gas, solid/CHP, solid/electricity, solid/solid and solid/oil.

A common variable comprising the 20 generic dwelling types, 22 possible fuel switches and the 5 SAP bands, and including up to 380 potential categories, is then computed for the EHCS and similarly for the SHCS and LIW survey samples.

For the imputation of the installation costs, the mean cost is determined for each of these categories from the results of the English model and then applied to the same categories in the Scottish and Welsh samples. To determine the total costs, the imputed means are simply multiplied by the number of occupied dwellings in each category in Scotland and Wales. Finally, the outputs are provided, broken down by each type of fuel switch, wall type and house/flat type.

To determine the energy savings, the same 380 potential categories are used to impute the energy requirements for space heating both before and after improvement. However, as the energy requirements for water heating, lights and appliances and cooking are less dependent on the thermal standard of the dwelling, each of these is imputed using only 76 categories, derived from the generic dwelling types and possible fuel switches alone. Also here the outputs for space and water heating, lights and appliances and cooking are provided, broken down by the fuel switch type alone. As in the calculation of fuel costs in the EHCS, dual fuel (gas and electric) cookers are assumed where there is gas heating, with all electric cookers being assumed elsewhere.

16.2 Northern Ireland

Equivalent public datasets to the EHCS, SHCS and LIW survey are not available for the 2004 Northern Ireland House Condition Survey. Consequently, for Northern Ireland, the imputation has had to rely on the tables available in the 2004 Interim House Condition Survey Statistical Annex, published by the Northern Ireland Housing Executive.

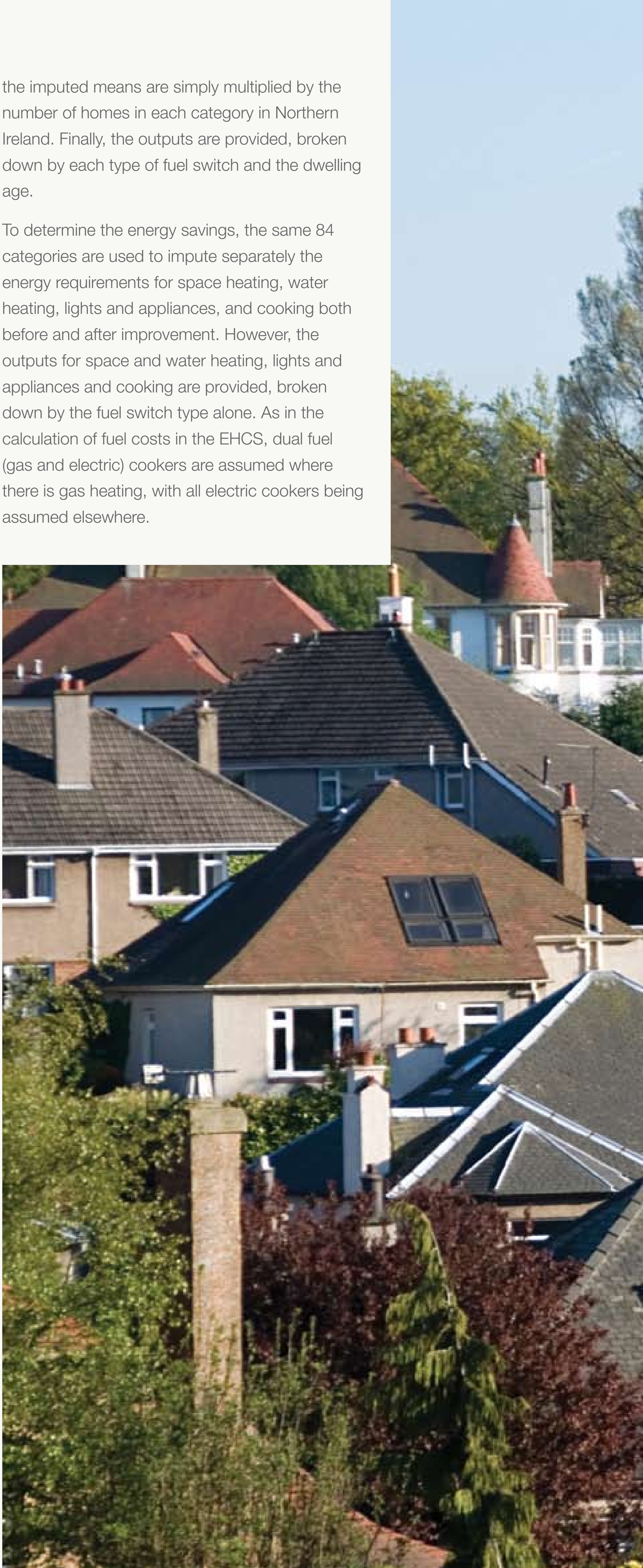
Although the NIHCS Statistical Annex provides breakdowns by SAP rating, none of these particular tables also provides a breakdown with the main fuel used in the dwelling. The latter is essential to determining the carbon savings generated by the energy (kWh) savings. However, tables of the main heating fuel are provided, broken down separately by tenure, dwelling age, built form, location and household characteristics. Of these, Table 7.2, showing the main fuel by the dwelling age, has been used in the imputation. Of the five variables available, the dwelling age/construction date provides the best proxy for the thermal standards of the housing.

The list of fuels provided by Table 7.2 includes dual fuels used for central heating, but the main NIHCS report records the primary fuel in most of these cases to be heating oil. The small percentage of other central heating is assumed to be LPG, while due to the traditional lack of mains gas in Northern Ireland, other non-central heating is assumed to be fuelled by electricity.

As with Scotland and Wales, the fuel used after improvement is not known. For each original fuel, the proportion of households switching to each new fuel is assumed to be the same as generated by the full improvement model for England. In this way, the grossed Northern Ireland sample of 680,000 homes is broken down into 22 types of fuel switch and each fuel switch further divided into up to five different dwelling ages. Assuming that, as in England, not all fuel switches have all five age bands, a common variable combining the fuel before and after improvement with the construction date, and comprising a total of 84 different categories, is finally created for both the Northern Ireland and England HCS samples.

For the imputation of the installation costs, the mean cost is determined for each of these 84 categories from the results of the English model and then applied to the same categories in Northern Ireland. To determine the total costs, the imputed means are simply multiplied by the number of homes in each category in Northern Ireland. Finally, the outputs are provided, broken down by each type of fuel switch and the dwelling age.

To determine the energy savings, the same 84 categories are used to impute separately the energy requirements for space heating, water heating, lights and appliances, and cooking both before and after improvement. However, the outputs for space and water heating, lights and appliances and cooking are provided, broken down by the fuel switch type alone. As in the calculation of fuel costs in the EHCS, dual fuel (gas and electric) cookers are assumed where there is gas heating, with all electric cookers being assumed elsewhere.



Annex VI
– Conservative assumptions

The study has made a number of conservative assumptions about the technologies that have been applied and the magnitude of savings generated. This conservative approach should reassure readers that the savings we present are achievable with concerted government action. Furthermore, the costs of the measures required and the magnitude of the savings generated represent the worst-case scenario. The measures associated with scenario 2 more than pay for themselves if projected system costs are used and the full payback is included – i.e. GVA, lifetime fuel savings and value of carbon.

17.1 Discount rates and cost of carbon

Scenario 1b represents a cost-effective scenario based upon a Treasury 3.5% discount rate for the savings achieved. The study could have alternatively looked at those measures deemed cost-effective when the value of carbon has been added (see Analysis of cost-effectiveness). However, the majority of measures become cost-effective when the value of carbon has been added; meaning scenario 2, where all measures are applied, represents this carbon valued scenario. While this definition of cost-effective would be even more holistic than that used for scenario 1b, the installation rates required would be even more challenging and almost certainly not possible by 2020.

17.2 Areas of Outstanding Natural Beauty

The *How Low?* study has assumed that solar power systems and internal/external wall insulation will not be applied systematically to listed buildings or to homes in conservation areas. While there are clearly further carbon savings to be made, there is likely to be significant public resistance to the wide-scale deployment of micro-renewables and external cladding in rural communities and historic towns. The negative press coverage of large-scale wind generation suggests that the further deployment of these measures is unlikely to be politically favourable at present.

17.3 Green gas percentage

Ernst & Young's recent study of the initial business case for supporting the UK renewable heat sector did not examine the feasibility of biogas injection to the domestic gas supply network. However, a response to the Renewable Heat Obligation consultation by Panthol Ltd[76] (a supplier of domestic oil and biofuels) stated that the UK could possibly secure 10% of its current natural gas energy needs, or 15% of its current electricity needs, by 2020, through the production and use of biogas from indigenous UK agricultural output. The study has therefore made a conservative assumption of a total residential green gas supply of 10% by 2050.

17.4 Decarbonisation of electricity

The report team has linearly extrapolated the projected carbon intensity of delivered electricity (2008-20) to estimate a 2050 carbon factor of 0.059kgC/kWh (see Figure 2). The recent IPPR, RSPB and WWF study to identify whether it would be possible to reduce the UK's carbon emissions by 80% of 1990 levels by 2050 identified decarbonised electricity as a key measure – i.e. a carbon factor of 0.005kgC/kWh. For reasons of conservatism this study has not assumed as high a level of decarbonisation as the IPPR report, which took a downward path to a zero carbon electricity sector by 2050. This serves to highlight that there is room to manoeuvre and go beyond an 80% cut in the residential sector.

17.5 Measures costs – mass marketing LZC technologies

Scenario 2 requires a total expenditure of £130 billion, with a GVA of £38 billion. This cost is based on today's prices for insulation and LZC technologies, which are likely to fall significantly between now and 2050. The recent Renewables Advisory Board (RAB) report on the 'Essential role of renewables generation in achieving zero carbon homes' examined the projected cost of LZC technologies from 2007 to 2025. If the cost reductions predicted are applied to scenario 2, costs fall by £36 billion to £94 billion in total, which would mean that as compared to the £99 billion cost of this scenario, they achieve a net positive economic position.

17.6 Fuel prices

This represents a conservative estimate of the actual savings achieved, as the fuel prices are based on 2007 averages. The DTI baseline projections for fuel prices by 2020, shown below, demonstrate an average price rise of 21%. If the figures for each fuel are applied to the lifetime savings generated at 2007 fuel prices, the total savings for scenario 1a and 1b rise by 25% and 13% respectively. Conversely, they fall for Scenario 2a and 2b, as electricity has the largest overall price rise, and this scenario creates an additional demand for this fuel.

17.7 Measures lifetimes – 15 years

The study has assumed a 15-year lifetime for all measures. This is a conservative estimate based on the shortest lifetime among the measures applied. The insulation measures and solar power systems typically have a 20-30 year lifetime. If a 20-year lifetime were applied, the lifetime savings would increase by 33%.

Fuel	2020 increase
Solid fuel	7.5%
Gas	16.5%
Electricity	40.5%
Oil	19.4%

76 Panthol Ltd (2007).

With thanks to:

Association for the Conservation of Energy

www.ukace.org

Centre for Sustainable Energy

www.cse.org.uk

Dr Richard Moore

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