www.bre.co.uk

BRE Client Report

EPISCOPE Pilot Project: England

Prepared for: Intelligent Energy Europe Programme for the European Union

Date: 29th March 2016

Report Number: 297809

BRE
Watford, Herts
WD25 9XX

Customer Services 0333 321 8811

From outside the UK:
T + 44 (0) 1923 664000
F + 44 (0) 1923 664010
E enquiries@bre.co.uk
www.bre.co.uk

Prepared for:
Intelligent Energy Europe Programme for the European Union
1210 Brussels, Belgium

Prepared by

Name	Claire Summers
Position	Senior Consultant
Date	29 March 2016

Authorised by

Name	Jack Hulme
Position	Principal Consultant
Date	29 March 2016

Co-funded by the Intelligent Energy Europe Programme of the European Union

EPISCOPE

Executive Summary

UK Government targets aim to reduce national greenhouse gas emissions (from all uses) by 80% by 2050 when compared to the position in 1990. Progress towards this target has already been made in the housing stock through improvements in energy efficiency. The average SAP rating (energy efficiency based on fuel costs) has risen, and CO_2 emissions have fallen. Significant further improvements, however, are required in the housing stock to meet the 2050 targets.

The results of the analysis of possible future energy efficiency scenarios for English housing are presented in this report in terms of CO_2 and energy use. English Housing Survey data from 2012 is used to calculate the potential for the installation of a number of energy efficiency improvements, and these improvements are applied in four scenarios representing 2050. The modelling which these scenarios are based on is the BRE Domestic Energy Model (BREDEM) and its derivative the UK Standard Assessment Procedure (SAP). Other factors such as population and emission factor changes have also been taken into account. Finally a modelled–to-real ratio has been calculated and applied to the scenarios to adjust notional emissions to be closer to the actual emissions.

Base modelling of the 2012 EHS data gave total CO_2 emissions to be 124Mt/year, this equates to approximately 5,700 kg of CO_2 per household per year in England in 2012. Applying a modest improvement package lowered the CO_2 emissions by 34% from 1990 levels. Two moderately ambitious scenarios both gave savings of approximately 50% from the baseline 1990 figure. The targets for 2050 are only met by the most ambitious scenario which saves 88% from 1990 levels.

In order to achieve the improvements to the residential stock required for the most ambitious scenario, increases in the number of improvements to the stock and changes to the market for measures such as solid wall insulation, heat pumps and alternative energy sources such as PV will be required. Increases to the rates of installation of these measures will be needed rapidly in order to meet the target required in the relatively short timescale. It is possible that current rates of loft insulation, cavity wall insulation and double glazing will be sufficient if implementation of these measures continues to be encouraged by government incentives and legislation. Rapid increases in the number of other measures installed alongside these mainstream measures, such as solid wall insulation and heat pumps, are however essential to meet the overall targets.

Greater potential for savings exist in the single family homes and terraced homes, reflecting their prevalence in the stock, their current large contribution to CO_2 emissions, and greater potential to install a greater range of measures.

Table of Contents

1 Introduction

UK Government targets aim to reduce national greenhouse gas emissions (from all uses) by 80% by 2050 when compared with the position in 1990. Progress towards this target has already been made in the housing stock through improvements in energy efficiency in England. The average SAP rating (energy efficiency based on fuel costs) has risen, and notional CO_2 emissions have fallen.

Significant further improvements are required in the housing stock to meet the 2050 targets. Further progress requires a reduction in heat losses from the existing housing stock by improving the fabric of the dwellings through greater insulation (e.g. cavity wall, loft or solid wall insulation) and upgrades to the heating of the existing housing, through installing systems that produce less emissions. Additional potential to reduce CO_2 emissions associated with the housing stock exists through the installation of renewable energy technologies and the provision of low or zero-carbon heat.

In recent years, a number of scenario analyses have attempted to quantify the potential for improving the energy efficiency of English housing, and the resulting benefits in terms of reduced greenhouse gas emissions and energy consumption from the housing stock. Among the most notable are estimates produced by BRE (Shorrock et al, 2005), the Environmental Change Institute (Boardman et al, 2005) and the Committee on Climate Change (e.g. CCC, 2008). These reports identify significant theoretical potential for enhancing the energy efficiency of the housing stock in England, and typically outline trajectories for reducing emissions.

Despite the theoretical potentials, improvements in energy efficiency are, however, proving difficult to achieve in practice. There are significant difficulties in accurately calculating energy consumption in both the pre- and post- improvement housing stock and numerous practical barriers also exist to the successful implementation of energy efficiency improvements on the ground. The modelling being undertaken as part of the IEE project EPISCOPE, attempts to account for the effect of these barriers in estimates of savings.

This report focuses on future potential scenarios for the domestic housing stock in England. Analysis is based on the primary energy modelling technique used in the UK: the BRE Domestic Energy model (BREDEM) (Henderson & Hart, 2015), and its derivative the Standard Assessment Procedure (SAP) (DECC/BRE, 2011). These methodologies are extensively used to predict the annual energy consumption in dwellings: SAP includes space and water heating and lighting energy use, and BREDEM also includes electrical appliances and cooking energy use. The CO_2 emissions produced from the housing stock can be deduced directly from energy use, and the prediction of housing-related CO_2 emissions through to 2050 will continue to rely heavily on the SAP and BREDEM methodologies. The analysis in this report uses these methodologies as a base to model future scenarios, and applies changes to emission factors and population to improve models of future demand. Finally a set of modelled-to-real factors are applied to each scenario to adjust the modelled output to a more realistic demand.

The modelling method undertaken is a ‘snapshot’ approach, giving final CO_2 emission figures in 2050 if all improvements identified are undertaken for each of the four scenarios specified. This gives a first estimation of how the 2050 targets could be achieved, and it is possible to estimate an indication of the type of changes to the current refurbishment trends (in type and rate) that will be needed to meet these targets (e.g. where market changes in rates and type of improvement will need to be implemented to meet these targets).

2 Description of the project

2.1 Data Sources

Modelling of energy efficiency and CO_2 emissions was carried out using data from the English Housing Survey (EHS) (DCLG, 2014a). The EHS is a national survey of housing in England, commissioned by the Department of Communities and Local Government (DCLG). The EHS covers all tenures and includes physical inspections of a representative sample of properties by professional surveyors alongside interviews held with the householders. The information obtained through the survey provides an accurate picture of the type and condition of housing in England, the people living there, and their views on housing and their neighbourhoods. Using the EHS for this project allows a 'case-by-case' analysis of dwellings (i.e. each case on the EHS dataset can be manipulated individually).

Additionally data from the 2011 Energy Follow-Up Survey (EFUS; See Hulme et al., 2014) was used to help understand how modelled energy use related to actual energy use. The Energy Follow-Up Survey is so called because it revisits dwellings and households first visited as part of the EHS. By revisiting EHS properties, the data from the earlier survey (for example on the household type, or physical characteristics of the dwelling) can be combined with the data from the EFUS. This provides a much richer data source for analysis. The EFUS consists of an interview survey, temperature monitoring, meter readings and electricity profiling of a sample of households.

The EHS and EFUS data have been scaled up to represent the national population (and to correct for non-response) using weighting factors. The 2012 combined year dataset of the EHS provides 12,763 cases (6,459 cases in 2011, 6,304 cases in 2012). The cases are weighted to be representative of the English housing stock, with a population of 21.9 million households in 2012 and 22.7 million dwellings (including vacant properties) (the most current published data available at the time of modelling).

Household weighting factors were used as the modelling is interested in the actual emissions from households, rather than the theoretical efficiency of the English housing stock (dwelling level, where vacant dwellings are also included in the energy and CO_2 calculations). This differs from the published SAP and CO_2 figures from DCLG, which are based on dwelling level analysis regardless of whether the household is occupied.

2.2 Modelling Method

The energy calculations were performed using the key energy modelling methodologies in use in the UK: the BRE Domestic Energy Model (BREDEM) (Henderson & Hart, 2015) and its derivative the UK Standard Assessment Procedure (SAP) (DECC/BRE, 2011). These methodologies are extensively used to predict the annual energy consumption in dwellings; BREDEM includes estimates for space and water heating, lighting, electrical appliances and cooking energy use; whereas SAP includes space and water heating and lighting energy use. The CO_2 emissions can be deduced directly from energy use, and the prediction of housing-related CO_2 emissions through to 2050 in the UK are likely to continue to rely heavily on the SAP and BREDEM methodologies. The SAP methodology assesses how much energy a dwelling will consume when using standardised assumptions for occupancy and behaviour, allowing comparison on a like-for-like basis of dwelling performance. Outputs include notional energy use per unit floor area, an energy efficiency rating and CO_2 emissions.

2.3 Scenarios

Initial baseline statistics of energy efficiency levels and CO_2 emissions were calculated using the SAP and BREDEM methodologies above for the English housing stock using the two year 2012 EHS dataset. The SAP 2009 methodology was used (as this was the model available for the EHS data at time of modelling). A retrofit package (e.g. a combination of solid wall insulation, loft insulation etc. where calculated to be appropriate) was then specified and applied within the model, which adjusted the base data to simulate the effect of the installation of these measures. The required energy metrics were then recalculated (i.e. a post-retrofit position) and can be compared with the pre-retrofit data to assess the improvement from the base position.

The scenario analysis is carried out on an individual case basis, and measures are installed where the current level in the dwelling is deemed to be suitable for upgrade (e.g. cavity wall insulation is installed in a dwelling if it currently has unfilled cavity walls).

Details of the criteria and specification of the scenario runs used for this analysis are outlined in sections 2.3.1 and 2.3.2 below.

2.3.1 Specification of improvement scenarios

The specification of four scenario runs (S1-S4) have been created for this project, to show varying levels of improvement in the housing stock to 2050. The scenarios increase in ambition (in the number and type of improvement) with S1 considered relatively modest to achieve and S4 being the most ambitious and including levels of measures which will require step changes in current practices to meet.

Improvement measures included in the scenarios are:

- Wall insulation (cavity and solid)
- Loft insulation
- Double glazing
- Heating upgrades (gas condensing boiler or electric heat pump depending on the scenario and location of the dwelling)
- Solar water heating
- Photovoltaics

Additionally, assumptions about changes to lights and appliances and the electricity carbon factor have been applied to each scenario.

A summary of the scenarios, and further details of the improvements included in each are shown in Table 1 below. A detailed specification of the decision making process used to decide when a dwelling is suitable for an upgrade for each of the measures above is given in section 2.3.2 below.

bre

Table 1: Summary of improvement measures by scenario

Position	Description	Measures included	Lights and appliances assumption (see section 2.5 for more detail)	Electricity carbon factor applied (see section 2.6 for more detail)
BASE	A summary of today's position. Where are we now? Base is 2012 EHS data.	• None	Standard SAP and BREDEM methodology assumptions	0.517
S1	Modest scenario with relatively 'simple' measures, in line with current trends.	• Includes all standard upgrades to **cavity wall insulation and loft insulation**. • Those suitable to upgrade to a **condensing gas boiler**, do so if the current boiler is over 12 years old, and gas (see Table 2). • Those shown to be suitable for **heat pumps**, and are currently over 12 years old, and also already have a radiator distribution system (see Table 2).	0% change (from standard SAP and BREDEM methodology assumptions)	0.165
S2	A scenario with insulation upgrades which do not include hard to treat solid wall insulation, and the merging of heating upgrades to efficient gas boilers.	• Includes all of the upgrades in the previous scenario. • Upgrade all **hard to treat cavity walls and loft insulation.** • Upgrade all **standard upgrade solid wall insulations.** • All **double glazing**. • Upgrade all remaining existing boilers, regardless of age (including fuel switch) to a **condensing mains gas boiler** where gas condensing boiler suitable (see Table 2). • All others suitable for **heat pump** upgrades, where the existing heating systems are over 12 years old, and any remaining existing radiator systems (see Table 2).	0% change (from standard SAP and BREDEM methodology assumptions)	0.032

bre

Table 1 (cont'd): Summary of improvement measures by scenario

Position	Description	Measures included	Lights and appliances assumption (see section 2.5 for more detail)	Electricity carbon factor applied (see section 2.6 for more detail)
S3	A long term scenario where heating systems follow current trends of **mains gas boilers** and **all households are insulated** to a good level, and **electricity generation is included**.	• Includes all of the upgrades in the previous scenarios. • Upgrade all **hard to treat solid walls**. • All others suitable for **condensing mains gas boiler** upgrades, install remaining boiler upgrade potential (see Table 2). • All remaining suitable for **heat pump upgrades**, install remaining heat pump upgrade potential (see Table 2). • Upgrade all **solar water heating** where appropriate. • Upgrade all **photovoltaics** where appropriate.	-35% change (from standard SAP and BREDEM methodology assumptions)	0.032
S4	A long term scenario where heating systems follow alternative trend of **high levels of heat pumps**, and **all households are insulated** to a good level, and **electricity generation is included**.	• Includes **all of the fabric improvements** as in the previous scenarios. • ALL heating upgrades are **heat pumps** (where the household is rural or suburban) and **condensing gas boiler** (where the household is urban) (see Table 3). • Upgrade all **solar water heating** where appropriate. • Upgrade all **photovoltaics** where appropriate.	-35% change (from standard SAP and BREDEM methodology assumptions)	0.032

2.3.2 Scenario criteria

Analysis of the baseline data was carried out to determine the number of basic energy efficiency measures which could be installed into existing dwellings using the criteria given below.

a) Cavity wall insulation

Cavity wall insulation is added to all dwellings with a predominant uninsulated cavity wall type. This is split into standard and hard to treat upgrades, as far as possible using the data available.

- **Standard fillable upgrade**

  Undertaken when no compelling physical barrier to installation exists. Usually bungalows or two storey houses with standard masonry cavity walls and masonry pointing or rendered finishes.

- **Hard to treat upgrade**

  These are homes with cavity walls that could in theory be filled, but which exhibit one of the following difficulties:

  1. They are in a building with three or more storeys, where each storey has cavity walls. The need for scaffolding to install insulation in these higher buildings, and unsuitability of some cavity wall insulation systems, would contribute to the complication and cost of improving these homes.

  2. The gap found in the cavity wall is found to be narrower than in standard walls. Although an attempt could be made to insulate these homes by injecting foam, the limited cavity space may lead to an uneven spread of the insulating material, resulting in substandard thermal properties and / or problems with moisture ingress.

  3. The dwelling is of predominantly prefabricated concrete, metal or timber frame construction. Although more recent examples of these homes will have had insulation applied during construction, these are generally unsuitable for retrospective treatment. In the case of timber frame construction, the industry recommendation is not to inject insulation as this can hamper ventilation between the frame and the external wall that may lead to rot in the timber frame.

  4. The cavity wall has an outer leaf finished predominantly with tiles or cladding. These surfaces may provide a physical barrier to successfully installing the insulation.

b) Solid wall insulation

Solid wall insulation is added to all dwellings with a predominantly uninsulated solid or 'other' wall type (i.e. Walls other than traditional cavity and solid wall types such as timber, concrete frame etc.). This is split into standard and hard to treat upgrades:

- **Standard upgrade**

  Currently uninsulated non-cavity walls which do not have any of the physical barriers which are listed below.

- **Hard to treat upgrade**

  1. Masonry-walled dwellings with attached conservatories or other features.
  2. Dwellings with a predominant rendered finish.
  3. Dwellings with a predominant non-masonry wall finish.
  4. Flats.

bre

d) Loft insulation

Loft insulation is added to all dwellings with current loft insulation of less than 300 mm mineral wool. It is upgraded to 300 mm mineral wool. This is split into standard and hard to treat upgrades:

This is split into:

- **Standard upgrade**

  Installation would be straightforward with no barriers.

- **Hard to treat upgrade**

  1. Boarded loft: Loft is boarded across the joists which would lead to extra work and expense.
  2. Room in roof: Insulation would need to be added between the rafters which would involve very extensive work and considerable cost.
  3. Flat or shallow pitched roof: not feasible to install loft insulation as there is no access into the loft or no loft space.

e) Double glazing

Double glazing is added to all dwellings to replace existing single glazed windows.

f) Solar water heating

Solar water heating of $3m^2$ is added to all houses (excludes flats) where no existing solar water heating exists, and a suitable roof space is available. This is where the surveyor has indicated that there is space on the roof to install solar panels, and also where the roof is facing south, south-west or south-east.

g) Photovoltaics

Photovoltaics of 2.5 kWp are added to all houses (excluding flats) where no existing photovoltaics exist, and a suitable roof space is available. This is where the surveyor has indicated that there is space on the roof to install PV panels, and also where the roof is facing south, south-west or south-east.

h) Heating upgrades

Heating upgrades have been limited to two options for this analysis. The first option is upgrading to an efficient mains gas condensing boiler, reflecting the most common and efficient mainstream option currently readily available. The second option is installing an electric air source heat pump, reflecting the likely future need to move towards higher efficiency electric heating systems.

The heating system upgrade choice is defined by two criteria; a) type of heating to upgrade to and b) complexity of the upgrade. The details of these are given below.

Type of heating:

Heating upgrades are applied to each of the households, depending on which of the criteria the dwelling falls into. The rules shown in Table 2 apply to scenarios S1-S3. For S4 scenario, the rules are altered such that all those households in urban areas are set to have mains gas boilers installed, where a heating upgrade is appropriate, and all households in a suburban or rural location are set to have heat pumps installed (Table 3).

bre

Complexity of upgrade:

The complexity of the heating system refurbishments are designed to increase from scenario S1 to S4. This reflects the greater cost and difficulty of installing heating systems where the heating will require total renovation compared to simpler upgrades. The details of these upgrades for each scenario are split into criteria based on whether the upgrade is a boiler or a heat pump (as identified in the heating upgrade matrix (Table 2 or Table 3):

S1: If there is potential to upgrade to a condensing gas boiler, do so if the current boiler is over 12 years old, and gas. Those shown to be suitable for heat pumps, upgrade if the current heating system is currently over 12 years old and already has a radiator distribution system.

S2: Upgrade all those in S1 criteria, and additionally all eligible existing boilers, regardless of age (including fuel switch), and those eligible for heat pumps where the original system are over 12 years old or any remaining existing radiator systems.

S3: Upgrade all those in S1 and S2 criteria, and all remaining potential for condensing boilers and heat pumps.

S4: Upgrade all to either condensing boiler or heat pump.

Table 2: Heating upgrade matrix for S1, S2 and S3

		Flats	Houses
On gas	**Rural**	Condensing gas boiler	
	Urban		
Off gas	**Rural**	Heat pump	Biomass boiler / Heat pump
	Urban	Heat pump	Heat pump

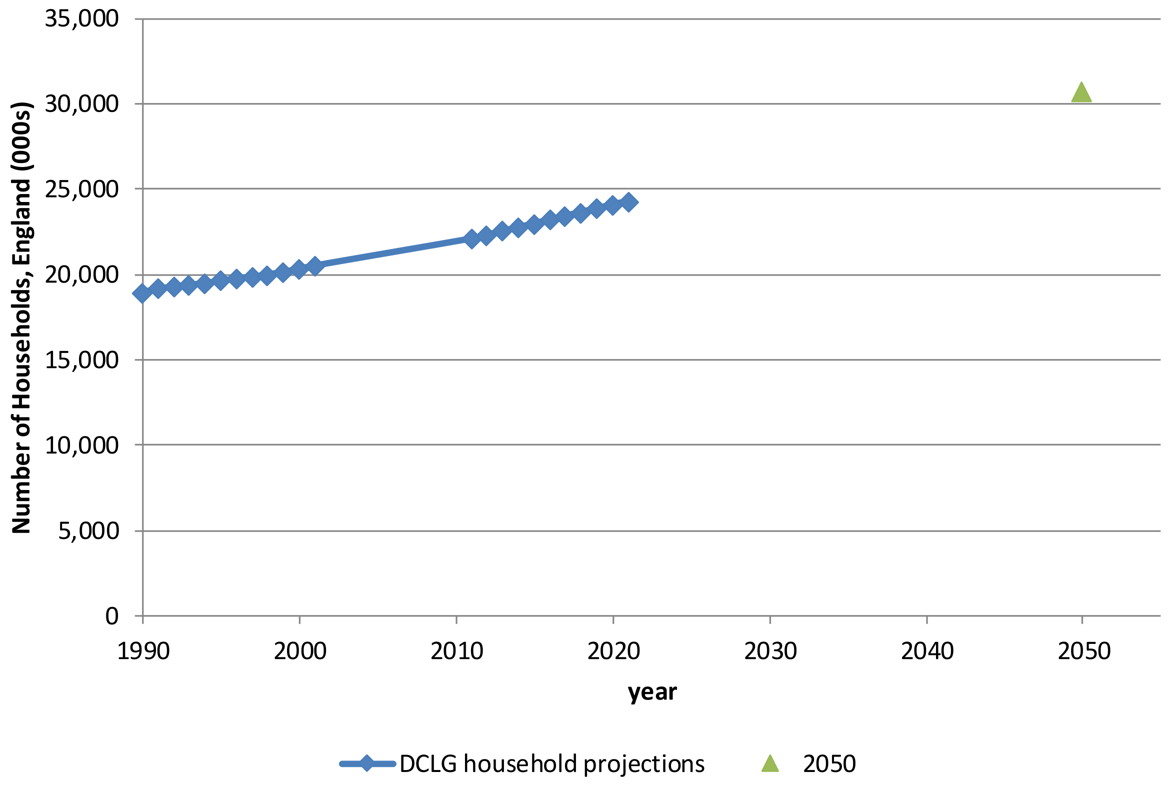
Table 3: Heating upgrade matrix for S4

	Heating Type
Urban	Condensing gas boiler
Suburban	Electric heat pump
Rural	

2.4 Population changes

Household projections to 2050 have been modelled to assess the impact that population increases will have on the energy efficiency of the English housing stock (Figure 1). The projections up to 2021 use estimates from DCLG (DCLG, 2013a), which use the 2011 census as a base. The 2050 household projection has been estimated using a simple linear extrapolation based on the DCLG projections from 2011 to 2021 (an increase of 221,000 households per year on average). This projection gives an estimate of 30.7 million households in England in 2050. The projections are not an assessment of housing need or future policy, but are an indication of the likely increase in households given the continuation of recent predicted trends.

Figure 1: Household projections to 2050



This analysis does not assess the provision of measures applied in the new build to make them zero carbon (e.g. the total measures required for 2050 do not include new build requirement). Therefore in the modelling scenarios to 2050 all population increases (from our base data of 2012) have attributed no carbon to the total as a result of new builds (as all new dwellings from 2016 should be required to contribute net zero carbon).

2.5 Lights and appliance improvements

Ownership of lighting and appliances in England has increased significantly over the past 40 years. Most of the fuel required for this change is met by electricity, and therefore these technologies contribute significantly to the UK's greenhouse gas emissions, and will become a more significant part of domestic fuel demand over time as the requirement for heating energy decreases with fabric efficiency improvements.

It is likely that the increases in the efficiency of lighting and appliances will lead to some decreases in energy demand over time, but it is very difficult to predict the future trends in electricity demand to 2050 with confidence.

Two future pathways have been created for lights and appliances, based around the projections for domestic lighting and appliance energy in the DECC 'Pathways to 2050' model (DECC, 2010).

1. **Stable: change 0%**
   This scenario keeps the total demand for energy for lighting and appliances stable at today's levels. This could be achieved by reducing the demand for lighting energy, white goods and cooking appliances through improvements in efficiency, which would counteract the increase in the energy used for consumer electronics and home computing.

2. **Significant decrease: change -35%**
   This scenario would require all lighting to meet with today's best practice LEDs by 2050, replacement of all white goods to reduce overall demand, implementation of ambitious efficiency improvements for consumer electronics and home computing to reduce demand significantly, in addition to improving consumer use of all these areas.

The stable change (0%) was applied to the S1 scenario and the S2 scenario. The significant decrease (-35%) was applied to the remaining, more ambitious, scenarios (S3 & S4). These changes have been applied to lighting, appliances and cooking energy use.

2.6 Carbon factors

Future electricity emissions factors have been included in the model due to the expected influence that they will have on residential carbon emissions. The values used have been taken from DECC system grid average projections (DECC, 2014b) and give an electricity emissions factor of 0.032 in 2050, which has been applied to the S2, S3 and S4 scenarios. A more conservative value of 0.165 has been applied to the S1 scenario, assuming a less ambitious decarbonisation of the electricity supply for this scenario.

Base carbon emissions factors are taken from the SAP 2009 methodology (DECC/BRE, 2011).

2.7 Modelled–to-actual ratio

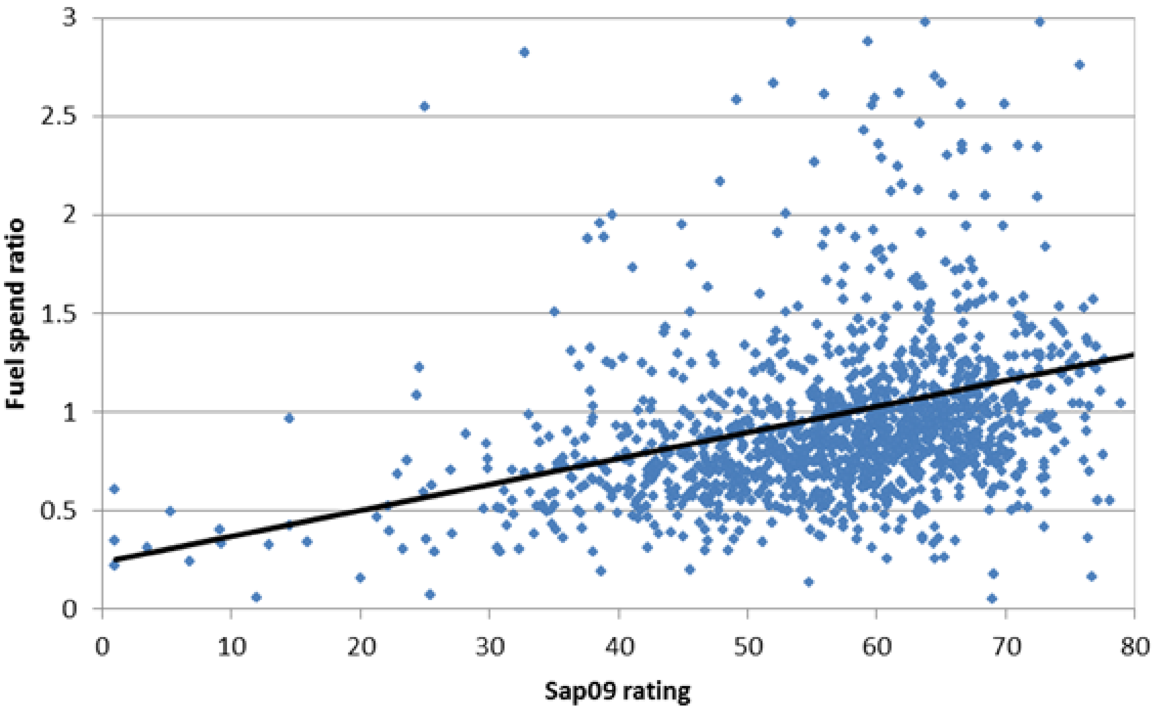
It is known that notional energy consumption and carbon emissions, as calculated under SAP, are greater than the actual energy consumption and emissions as recorded by the national statistics (i.e. the Digest of UK Energy Statistics (DUKES) in the UK (DECC, 2013)). To account for this correction factors have been applied which adjust the final SAP calculated energy requirement in order to be better aligned with the national accounts.

Analysis of the 2010 Energy Follow-Up Survey (EFUS) indicated a relationship between the SAP rating, and the ratio of differences between actual and notional energy consumption. This is shown in Figure 2 below, which plots the ratio of notional fuel expenditure to actual fuel expenditure (Fuel spend ratio) against SAP rating.

For EPISCOPE, the relationship between actual fuel spend and modelled outputs has been explored further, and equivalent relationships derived for carbon dioxide emissions and total energy consumption which act to align SAP derived notional values more closely with actual emissions.

The relationships imply that dwellings with higher levels of energy efficiency are more likely to achieve (or indeed exceed) the notional fuel consumption as calculated in SAP, and dwellings with lower levels of energy efficiency vice-versa. By applying this relationship in scenario analysis, as well as aligning the notional and actual emissions, this acts to simulate, at least to some extent, 'comfort taking' where a low energy efficiency household heats to higher temperatures or longer hours, following the application of energy efficiency measures.

Figure 2: relationship between fuel spend ratio and the SAP rating



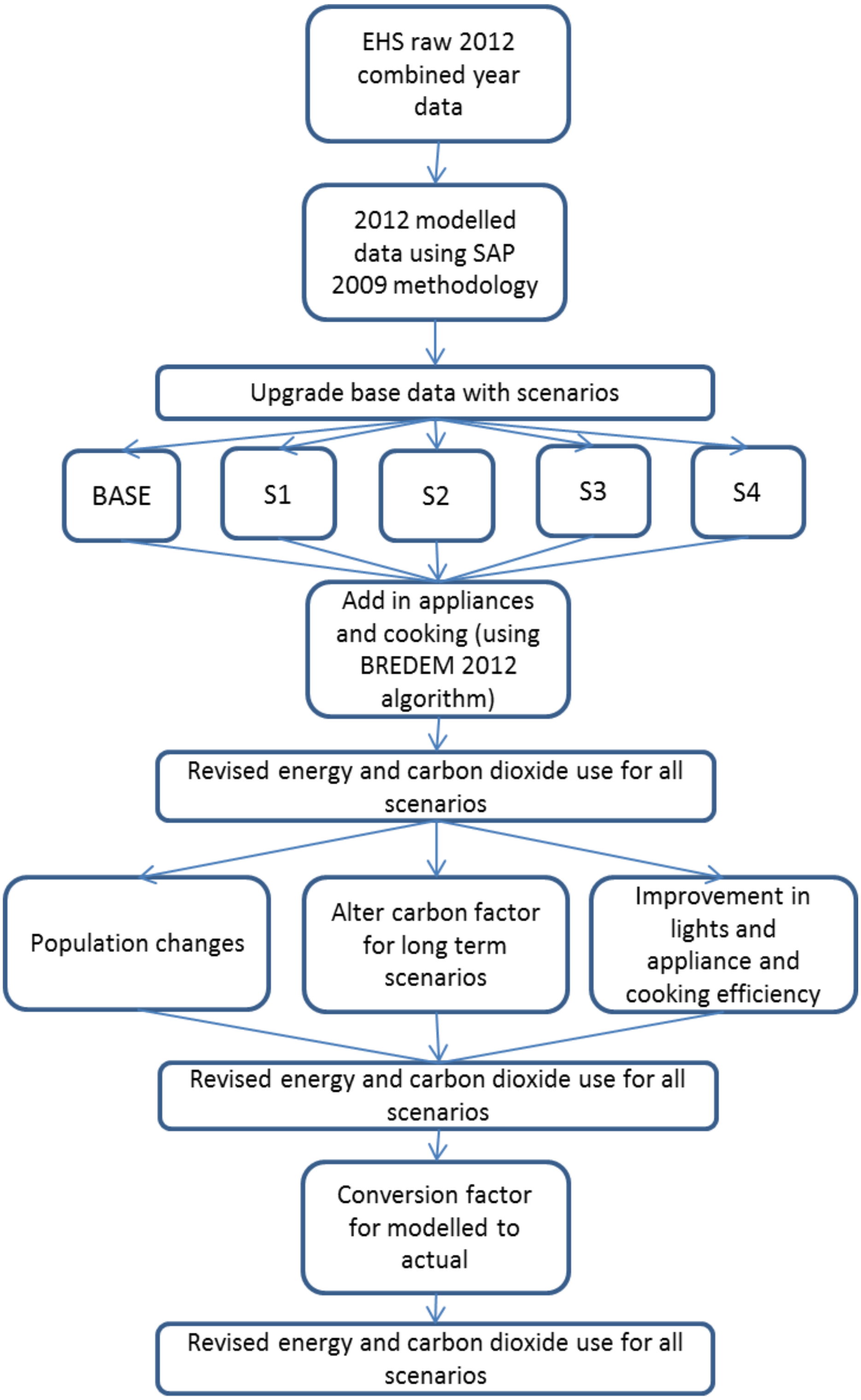
2.8 Modelling process

A flow chart of the modelling process and the outputs it produces is shown in Figure 3.

The modelling method undertaken is a ‘snapshot’ approach, giving final CO_2 emission figures in 2050 if all improvements specified are undertaken for each scenario. This gives a first estimation of how the 2050 targets could be achieved, and it is possible to estimate an indication of the type of changes to the current refurbishment trends (in type and rate) that will be needed to meet these targets (e.g. where market changes in rates and type of improvement will need to be implemented to meet these targets).

Identification of detailed pathways for refurbishment have not been examined in this current analysis, but the results of these interim findings could be built on in the future to provide more detailed year-on-year scenarios.

Figure 3: Flow chart of the modelling process



bre

3 Findings

The key headline findings from the scenario modelling detailed in the methodology are provided in this section. Firstly, an overview of the English building stock gives context for the modelling (3.1), and an initial summary of the current profile of the stock in terms of CO_2 and energy efficiency provides some background information to the current targets and progress towards them (3.2). This is followed by analysis of the potential for improvement in terms of heating systems and thermal characteristics of the stock (3.3). A summary of the results from each modelled scenario is then presented and discussed (3.4-3.7), and finally analysis of the potential for improvement is split by dwelling type and age (using the TABULA stereotypes as a base. See BRE, 2014 for more information) (3.8).

3.1 The English Building Stock: Overview

In 2012 there were 22.7 million dwellings in England, according to the English Housing Survey. Of these 20% were built before 1919, whilst 14% of the stock was built after 1990. The majority of properties in England are either terraced (28%) or semi-detached houses (26%). Some 17% are detached houses and 9% are bungalows. The remaining 20% of homes are flats (mostly purpose built low rise flats). The average (mean) useable floor area of dwellings in 2012 was 92m^2.

The majority of dwellings are situated in suburban residential areas (62%). 21% are in cities and other urban centres, and the remaining 17% in rural areas. Some 65% of dwellings are owner occupied, 18% are privately rented and the remaining 17% are rented from social landlords.

The vast majority of homes in England are served by an individual heating system. In 2012 91% of all homes had central heating; a further 7% had storage heaters as their main heating system with the remainder having room heaters. The main heating fuel used is natural gas (~85% of homes), followed by electricity (~10%) and oil (~5%). All others such as coal and other solid fuels and district heating are observed at very low levels overall.

The majority of English housing is of brick construction. There were 15.5 million cavity walled dwellings in the English stock in 2012, and the remaining 7.1 million are a mixture of solid walls, timber walls and other constructions (e.g. concrete).

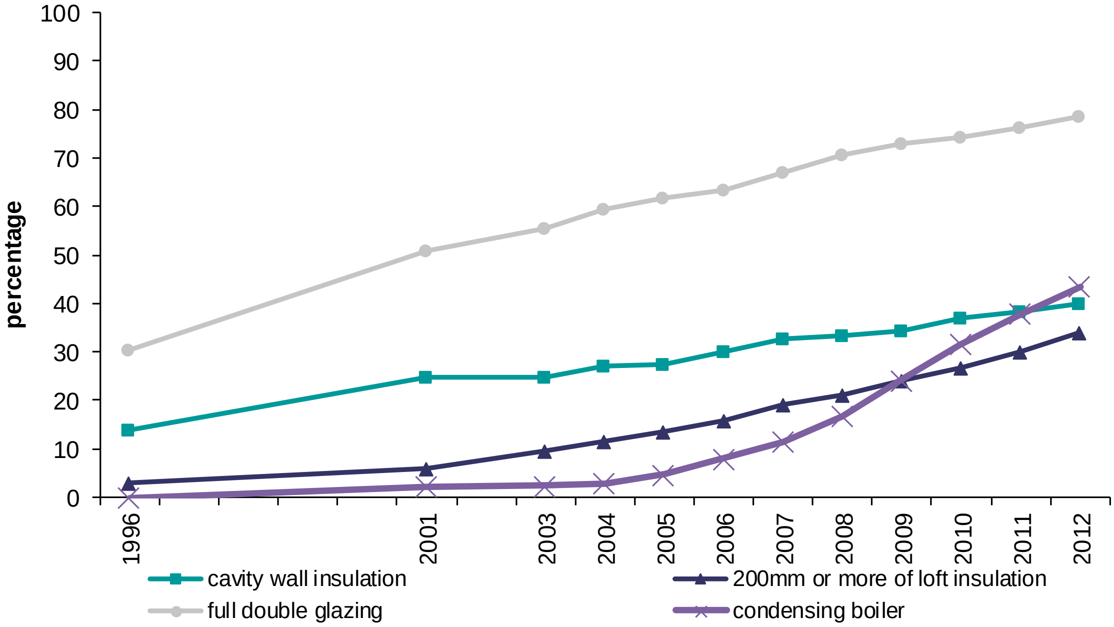
3.2 The current housing stock trends and targets: CO2 and energy efficiency

3.2.1 Energy efficiency

Domestic buildings in the UK are responsible for approximately 25% of emissions and just over 40% of its final energy use[1]. These 2009 figures represent a drop from 1990 levels. The decrease seen from 1990 is due to improvements in the fabric and heating systems of existing dwellings and the higher requirements for new dwellings (Figure 4) over recent years.

[1] 2009 figures from HM Government Carbon Plan (HM Government, 2013)

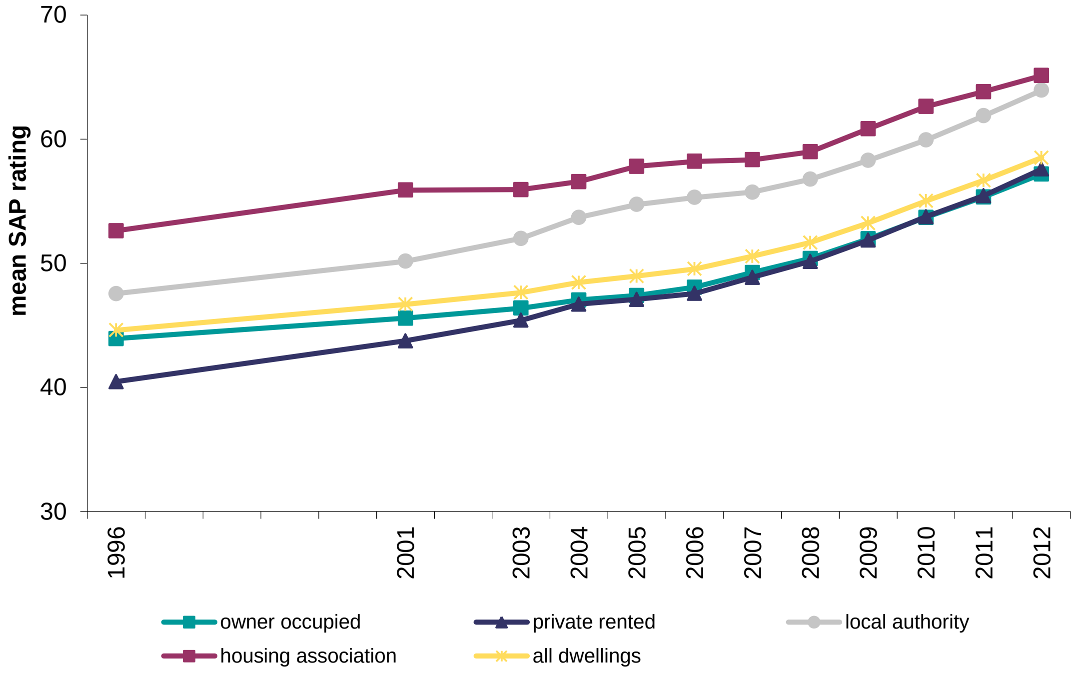
Figure 4: Insulation measures & condensing boilers, 1996 to 2012



- **Source: EHCS/EHS (DCLG, 2014b)**
- **Note: Percentages are based on all dwellings, including those with no loft or no cavity walls. 87% of all dwellings have lofts, and 69% have cavity walls**

The fabric of buildings has been improved by a large number of 'simple measures' being installed such as loft insulation and cavity wall insulations, which has been accelerated by government policies encouraging these measures to be installed. Heating systems have improved through increases in central heating installation, and new boilers having higher minimum standards (condensing boilers became mandatory in 2005). Consequently, the energy efficiency of the English housing stock has increased significantly in recent years. In 2012 the average SAP rating (energy efficiency rating based on fuel cost) of English dwellings was 59 points, up from 45 points in 1996 (DCLG, 2014b) (Figure 5).

Figure 5: Mean SAP rating, by tenure, 1996 to 2012.



Source: EHCS/EHS (DCLG, 2014b) Based on SAP 2009 methodology.

The challenge for the existing housing stock for the long term is to continue to tackle the thermal efficiency of the housing stock, much of which is older and/or 'harder to treat', alongside the decarbonisation of the heating and cooling supply (as the majority of heating is by mains gas).

3.2.2 Current rates of improvement

Current rates of installation of insulation measures as seen in the English Housing Survey data are shown in Table 4. Most insulation measures have relatively high incidence, apart from solid wall insulation, where the market is less developed and uptake levels are currently low. Floor and ceiling insulation are also rarely seen measures, and not commonly installed as part of current retrofit programmes.

Changes to the overall type of heating are much slower. However, individual boiler upgrades (i.e. replacement of boilers but not the overall type of system) show a high rate of change of 7% per year most likely due to their relatively short lifespan and legislation which has required that new boilers are condensing.

There are very low levels and rates of uptake currently of special systems such as photovoltaics, solar thermal and ventilation systems; although over very recent years Government policies (e.g. the feed in tariff for photovoltaics) have encouraged the uptake of some of these to varying degrees.

Table 4: Current rates of installation of insulation measures

	Complete building stock	Details
Walls		
Insulation improved (from original state)	~40%	Percentage of all dwellings with CWI or SWI. Assume 50% of post 1990 are insulated. EHS 2011 report (DCLG, 2013b).
Annual rate of insulation improvement	2%	
Roofs / upper floor ceilings		
Insulation improved (from original state)	~90%	Note this is all top floor flats and houses with some insulation present - and excludes any flat roofs and those with zero insulation. EHS 2011 report (DCLG, 2013b).
Annual rate of insulation improvement	4%	
Ground floors / cellar ceilings		
Insulation improved (from original state)	Very low	Considered very rare to have insulated floors in UK. No reliable figures available.
Annual rate of insulation improvement	Very low	
Windows		
Insulation improved (from original state)	~75%	Figures for full double glazing. EHS 2011 report (DCLG, 2013b).
Annual rate of insulation improvement	3%	

bre

3.2.3 CO_2

The Climate Change Act (HM Government, 2008) established a target for the UK to reduce its emissions by at least 80% from 1990 levels by 2050. This target represents an appropriate UK contribution to global emission reductions consistent with limiting global temperature rise to as little as possible above 2°C. To ensure that regular progress is made towards this long-term target, the Act also established a system of five-yearly carbon budgets, to serve as stepping stones on the way. The first four carbon budgets, leading to 2026, have been set in law (Table 5). The UK is currently in the second carbon budget period (2013-17). Meeting the fourth carbon budget (2023-27) will require that emissions be reduced by 50% on 1990 levels in 2025.

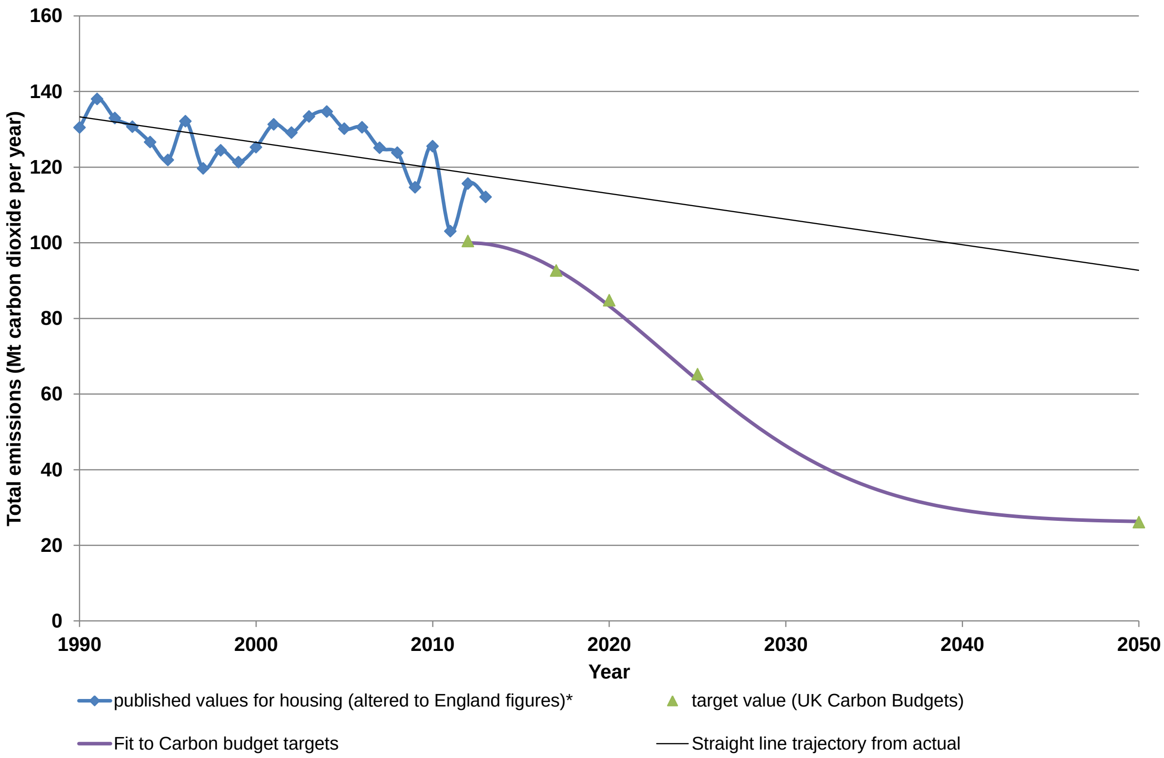
These budgets are set as targets for emissions across all sectors as a whole, rather than for housing in particular. In practice each sector may have more or less to contribute in terms of savings toward the total budgets into the future, however for this project the potential savings from housing are considered against these target percentage reductions (i.e. it is assumed that housing contributes no more or less than other end uses of emissions).

Estimates of UK greenhouse gas emissions from 1990 are published annually by source, end-user and fuel type by the UK Government department of Energy and Climate Change (DECC, 2014a). These statistics are used to monitor progress against the UK emission reduction targets. They are updated in March of each year and currently show statistics up to 2013. For this project the subset ‘domestic combustion’ figures from these tables have been used. The emissions estimates are given for the UK, and has been multiplied by a factor of 0.84 (reflecting the ratio of English/UK population) to represent an estimate of the English domestic combustion CO_2 emissions from 1990 to 2013 (Figure 6). This is overlaid by a straight line trajectory and also the targets calculated using the 1990 timeline data as a base for the reductions given in Table 5.

Table 5 Carbon budgets and targets (CCC)

Budget	% reduction below base year
1st Carbon budget (2008-12)	23%
2nd Carbon budget (2013-17)	29%
3rd Carbon budget (2018-22)	35% by 2020
4th Carbon budget (2023-27)	50% by 2025

Figure 6: Estimates of carbon dioxide emissions from 1990, and carbon budget targets to 2050 for residential combustion



*** Estimates of carbon dioxide (DECC, 2014a) reduced from UK to England by applying a factor of 0.84 (based on population proportions).**

To meet the targets shown in Table 5 and Figure 6 significant change to the current trends in CO_2 emissions from residential consumption will be required. This reduction will have to be met by improving the fabric and heating systems of the residential housing stock.

3.3 Potential for improvement

Using the criteria of the improvements detailed in the methodology, an assessment of the potential for upgrades was carried out using the 2012 English Housing Survey data. The numbers of improvements installed in each scenario are shown in Table 6.

Table 6: Improvements by scenario

Scenario	Improvement	Number (000s households)
S1	Cavity wall insulation: standard	4,233
	Loft insulation: standard	12,953
	Condensing gas boiler	4,029
	Heat pump	414
S2	**All above insulation measures and heating systems with the addition of:**	
	Cavity wall insulation: Hard to treat	1,121
	Loft insulation: Hard to treat	4,347
	Solid wall insulation: Standard	981
	Double glazing	4,684
	Condensing gas boiler	5,039
	Heat pump	1,400
S3	**All above insulation measures and heating systems with the addition of:**	
	Solid wall insulation: Hard to treat	5,137
	Condensing gas boiler Heat pump	491 745
	Solar water heating	14,306
	PV	14,380
S4	**All above insulation measures. All above solar water heating and PV Alternative heating system of:**	
	Condensing gas boiler	2,238
	Heat pump	17,274

3.4 Summary of scenario results

Headline results of carbon dioxide emissions and energy use from the scenario analysis are summarised in this section. More detailed tables splitting carbon dioxide and energy by end use in the household can be seen in Appendix A.

Figure 7 compares the UK Government's residential combustion CO_2 emissions from 1990 to 2013 (adjusted for England) (DECC, 2014a) with the model output results for the 2012 base and 2050. The Government UK figures have been adjusted to represent England by multiplying the UK figure by a factor of 0.84 (representative of the proportion of the UK population which lives in England). Fluctuations in the actual CO_2 trending are reflective of the variable energy use due to colder/warmer winters from 1990 to 2013. The 2012 baseline EHS modelled figure is reduced to be in line with the trend line of the actual data using the 'modelled-to-real ratio' as described in section 2.6. The 'modelled-to-real ratio' is also applied to the scenario results, however the effect of the real ratio on the scenarios in 2050 is smaller than the effect on the base, due to the improved nature of the stock and the ratio being closer to or above 1 at the higher levels of energy efficiency seen in the scenario results.

Figure 7: Scenario results in 2050

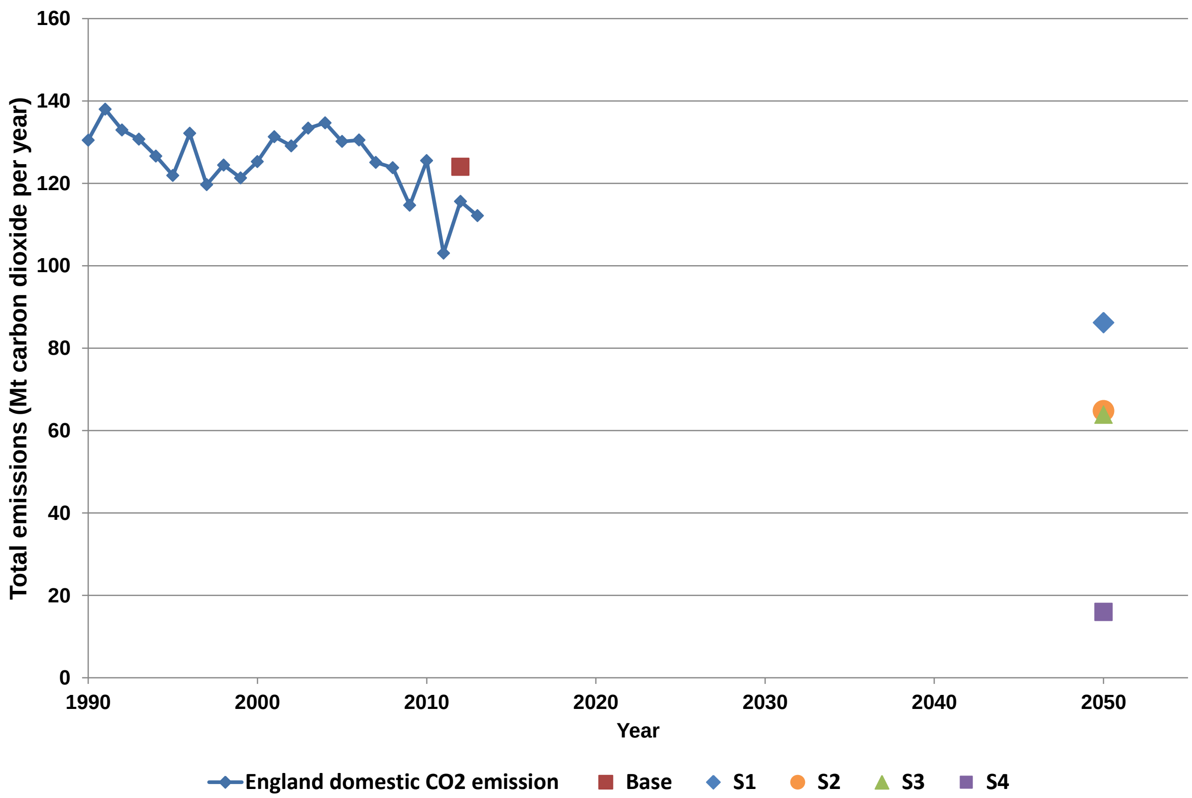


Table 7 summarises the headline scenario results for CO_2. Total CO_2 emissions for the English residential stock in 2012 English Housing Survey data are modelled to be 124 million tonnes per year. This equates to 5,652 kg of CO_2 per household per year in England in 2012. Applying the modest S1 scenario lowered CO_2 emissions by 34% in 2050 from 1990 levels. Scenarios S2 & S3 which still rely on the mains gas network as the main source of heating, both save approximately 50% by 2050 from the base 1990 figure.

Truly deep cuts to CO_2 are only possible with the installation of large numbers of electric heat pump systems, and associated decarbonisation as seen in scenario S4. Dependence on electric heating in the form of heat pumps, coupled with significant decarbonisation of the electricity supply system, in this scenario leads to cuts of 88% by 2050 from 1990 levels. This is the only scenario which is able to achieve the target in 2050 of reducing emissions by 80% from 1990 levels.

Table 7: Headline scenario results: CO_2

Scenario	Mt carbon dioxide/year	Compared to base (2012)*		Compared to 1990 levels**	
		% change	Mt/year change	% change	Mt/year change
BASE	124.0	-	-	-	-
S1	86.2	-30.5%	-37.8	-33.9%	-44.3
S2	64.8	-47.7%	-59.2	-50.3%	-65.7
S3	63.8	-48.5%	-60.1	-51.1%	-66.6
S4	16.0	-87.1%	-108.0	-87.7%	-114.5

***Modelled using 2012 English Housing Survey data using the SAP methodology, with BREDEM methodology appliance and cooking use and a 'real ratio' applied.**

****Estimate of CO_2 emissions for residential combustion using adjusted UK figure to represent England only.**

Table 8 shows the results for energy use. Total energy use for the English residential stock is modelled to be 424.9 TWh for 2012. Reductions for energy use have only been compared to 2012 levels. Scenario S1 reduced the energy use by 6.7%, S2 by 13.3%, S3 by 25.4% and S4 by 59.6% from 2012 levels.

The similarity in CO_2 savings for scenarios S2 and S3 initially appears as an anomaly, given that S3 also includes additional gas boilers, heat pumps and a large number of solar water heating and PV systems compared to S2. However, the 2050 carbon factor applied for electricity means that the CO_2 savings for energy technologies are considerably smaller than if decarbonisation of the grid had not occurred, and the application of the real ratio further reduces the difference between the two scenarios. Significant savings are still seen in energy use between the two scenarios (see Table 8), and thus overall electricity needed to be generated at power stations would be reduced which would benefit the CO_2 balance for the country when considering all sectors.

It is important to note when interpreting the scenarios that they may still overstate the actual realistic potential due to the fact that it assumes households have always upgraded to the most efficient type of system for their situation. Households may, in reality, upgrade to lower efficiency systems, insulation thicknesses etc. where regulations and circumstances allow. The realistic potential is analysed and discussed further in section 3.7 and Appendix B.

Table 8: Headline scenario results: energy use

Scenario	TWh/year	Compared to base (2012)	
		% change	TWh/year change
BASE	424.9	-	-
S1	396.6	-6.7%	-28.3
S2	368.3	-13.3%	-28.3
S3	316.8	-25.4%	-51.4
S4	171.9	-59.6%	-145.0

bre

3.5 Pathways to 2050

To model the potential pathways to meet the results of the 4 scenarios, S-curves have been created from the 2012 base position (taking the linear line point at 2012 through the existing published data as a base) to the scenario results in 2050. These are shown in Figure 8, Table 9 and Table 10. Figure 8 includes the carbon budget targets (as discussed in section 3.2.3), and it is clear that it is going to be difficult to meet the carbon budget targets without step changes in the current rate of reduction of the total CO_2 in the residential sector.

Figure 8: Potential pathways to 2050

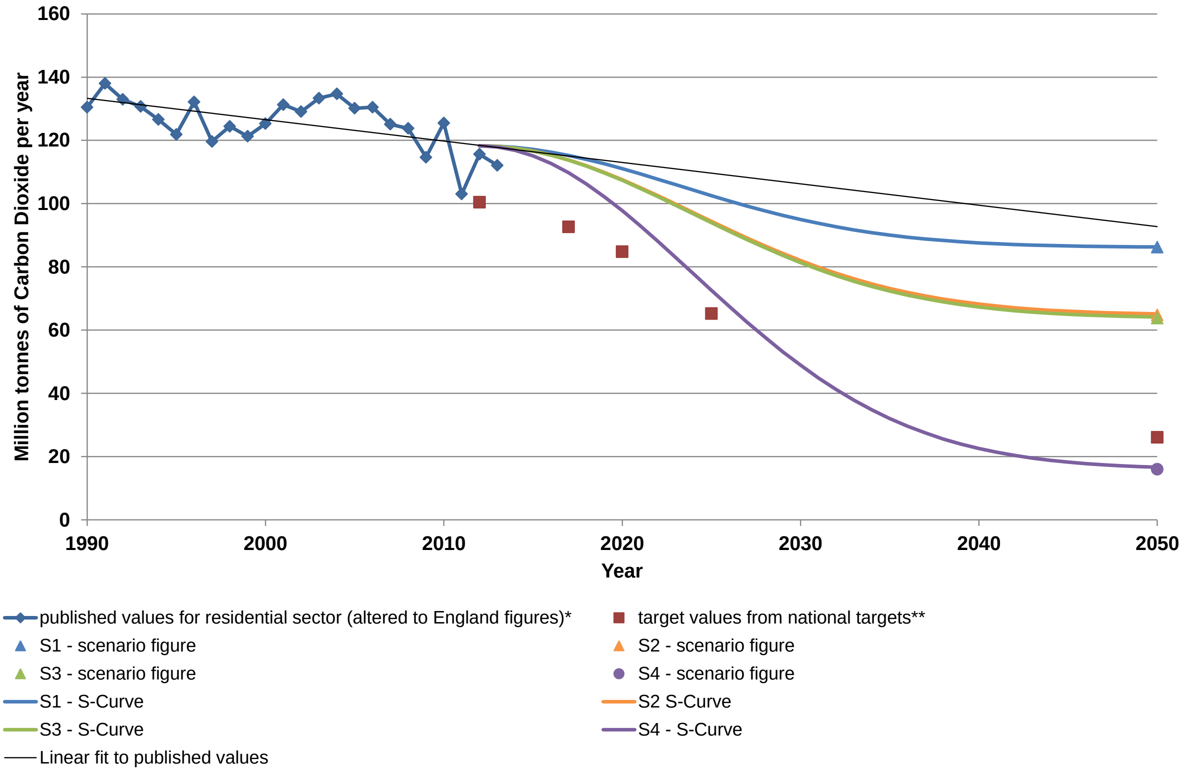


Table 9: Interim modelled CO_2 emissions to 2050: Total

	Total CO_2 emissions (Mt per year)			
	S1 (trend)	S2	S3	S4
2012	118	118	118	118
2015	117	117	117	115
2020	111	108	107	98
2030	95	82	81	49
2050	86	65	64	16

Table 10: Interim modelled CO_2 emissions to 2050: % change

	% change in CO_2 from 1990 levels			
	S1 (trend)	S2	S3	S4
2012	-9%	-9%	-9%	-9%
2015	-10%	-11%	-11%	-12%
2020	-15%	-18%	-18%	-25%
2030	-27%	-37%	-38%	-63%
2050	-34%	-50%	-51%	-88%

3.6 Implementation rates of improvements

Rates of improvement required to meet the scenario results above are shown in Table 11. Linear rates of change per year have been calculated, as a way of assessing the ease of meeting the 2050 targets, as compared to current 'business as usual' rates. Measures such as double glazing and loft insulation are already at high levels and improvements in technology to the future will help to meet the 2050 targets. The speed at which these targets are met will be driven by policies and incentives put in place to implement them.

Table 11 shows that, given current rates of installations, market changes are likely to be needed to implement the required number of installations of PV, solar water heating, heat pumps and solid wall insulation required if the 2050 targets are to be met. These changes in installation rates are unlikely to happen quickly enough on their own. Barriers to implementation of these technologies include currently the inconvenience and cost to the homeowner, physical constraints, along with a lack of knowledge of the technology.

Table 11: Rates of improvement required to meet scenario results by improvement type

Improvement	Description	2050 (linear rate per year 2012-2050)	% of all stock per year	Achieveable at current rates?
Loft insulation	Standard: under 150mm	127,810	0.58%	Yes
	Standard: over 150mm	213,055	0.97%	Yes
	Hard to treat: under 150mm	21,835	0.10%	Yes
	Hard to treat: over 150mm	92,565	0.42%	Yes
Cavity wall insulation	Standard	111,382	0.51%	Yes
	Hard to treat	29,505	0.13%	Yes
Solid wall insulation	Standard	25,819	0.12%	Yes
	Hard to treat	135,181	0.62%	No
Double glazing	Over 50%	65,512	0.30%	Yes
	Under 50%	59,086	0.27%	Yes
Solar water heating		376,478	1.72%	No
Photovoltaics		378,418	1.73%	No
Mains gas boiler	Standard scenario	251,562	1.15%	Yes
	Alternative scenario	58,882	0.27%	Yes
Heat pump	Standard scenario	67,350	0.31%	No
	Alternative scenario	454,583	2.07%	No

3.7 Taking a realistic approach

Within the English housing stock it is conceivable that it is possible to reach a near 100% saturation level of a number of insulation measures. It is likely that loft insulation and double glazing will reach near saturation levels as materials improve (for example, a higher standard and aesthetically sympathetic double glazing more available to fit into older dwellings with sash windows at affordable prices). Loft insulation could reach near saturation with some improvement in the technology. For example, currently most loft insulation installed is mineral wool, which requires a 300mm thickness to gain a good insulation level, and which can be considered impractical in many cases by householders who use their loft as a storage area. Replacing mineral wool with an alternative technology would help to improve standards while also allowing effective insulation in more difficult to treat dwellings.

At the present time it is hard to understand from a practical and financial sense how successfully solid wall insulation will penetrate the market as many barriers to this exist. Barriers to solid wall insulation are considerable in the English housing stock and are discussed in more detail in Appendix B, which includes barriers identified at a workshop of refurbishment practitioners. A set of scenarios have been run without solid wall insulation, and show that it is not *necessarily* critical to insulate solid walls in order to meet the 2050 targets (see Appendix B).

Heating systems are also likely to improve as they are relatively regularly upgraded and it is possible (and already proven) to implement legislation which requires upgrade to a minimum level (this has already been demonstrated by the successful uptake of condensing boilers over the last 10 years following legislation changes in 2005). Incentives are likely to be needed to implement the required number of installations of PV, solar water heating and heat pumps required if the 2050 targets are to be met. These changes in installation rates are unlikely to happen quickly enough on their own.

3.8 Analysis for the potential for improvement, split by dwelling type and age

Housing stereotypes have been used to provide some initial analysis of the CO_2 savings by the age and type of household for each scenario. These stereotypes use the unified TABULA definitions in use in the EPISCOPE project (BRE, 2014). The results of this analysis are shown in Table 12, Table 13 and Table 14.

3.8.1 Base position

The base 2012 EHS CO_2 results (Table 12) show that terraced houses pre 1919 contributed 22.7 million tonnes of carbon dioxide to the modelled total. This equates to 16.3% of total CO_2. All terrace houses built pre 1980 contribute 49.3% of all CO_2, reflecting that they make up 49% of the entire English stock.

The highest level of CO_2 per household are the older single family homes, with those built pre 1919 in this group using just over 16,000 kg per household per year and those built between 1919-44 using just over 10,000 kg per household per year on average. Together these two groups contribute just under 11% of the total CO_2.

3.8.2 Scenario results

The largest percentage savings in the modest S1 scenario are seen in newer flats (apartments and multi-family homes post 1965) however due to the low number of these households in the overall stock, this does not equate to large total CO_2 savings. This trend is also seen for scenarios S2 and S3. For scenario S4 the largest savings are seen in the single family homes, perhaps reflecting the greater potential in these properties for savings relating to the installation of heat pumps.

The highest total savings is seen in the terraced houses due to their prevalence in the stock. Pre 1980 terraced houses have the potential to save 61 Mt per year under scenario S4.

The largest savings per household are seen in the older detached houses, which generally have the largest potential to improve individually, due to their high levels of CO_2 at a base level. After S4 has been applied, single family homes have the lowest average CO_2 emissions (528 kg/CO_2/yr), followed by terrace houses (650 kg/CO_2/yr). Apartments and multifamily homes both have higher levels of emissions per household after this scenario compared to other dwelling types, perhaps reflecting these housing types not being considered for some improvements in this scenario (e.g. PV/solar water has not been applied to flats and heat pumps have not been applied in urban areas, where flats are more prevalent).

The results shown in Table 13 and Table 14 could be used to target policies and future scenarios where more realistic application of measures are installed with more consideration of the specific situation of each stereotype of dwelling and the potential savings achievable (e.g. devise policies which target single family homes and terraced houses, as these show greater potential).

bre

Table 12: Base data (2012 English Housing Survey) statistics by housing stereotype

EPISCOPE stereotype: dwelling type and age categories	BASE			
	Number (000s Households)	Mt CO2 (modelled*)	% of total CO2	Per Household use (kg/yr) (modelled*)
SFH pre 1919	565	9.23	6.6%	16,345
SFH 1919-44	589	5.97	4.3%	10,143
SFH 1945-64	774	6.65	4.8%	8,599
SFH 1965-80	1,277	10.01	7.2%	7,839
SFH 1981-90	673	4.70	3.4%	6,987
SFH 1991- 2003	776	5.50	4.0%	7,088
SFH 2004+	272	1.77	1.3%	6,483
Terraced house pre 1919	2,866	22.69	16.3%	7,918
Terraced house 1919-44	2,777	17.81	12.8%	6,414
Terraced house 1945-64	2,880	16.22	11.7%	5,633
Terraced house 1965-80	2,217	11.76	8.5%	5,304
Terraced house 1981-90	802	3.67	2.6%	4,580
Terraced 1991- 2003	764	3.29	2.4%	4,312
Terraced house 2004+	407	1.57	1.1%	3,848
MFH pre 1919	837	5.02	3.6%	5,990
MFH 1919-44	297	1.31	0.9%	4,420
MFH 1945-64	663	2.75	2.0%	4,148
MFH 1965-80	954	3.76	2.7%	3,935
MFH 1981-90	385	1.30	0.9%	3,364
MFH 1991- 2003	368	1.24	0.9%	3,381
MFH 2004+	409	1.24	0.9%	3,041
Apartment pre 1919	18	0.14	0.1%	7,939
Apartment 1919-44	20	0.10	0.1%	4,904
Apartment 1945-64	105	0.43	0.3%	4,113
Apartment 1965-80	139	0.55	0.4%	3,975
Apartment 1981-90	10	0.04	0.0%	4,341
Apartment 1991- 2003	22	0.08	0.1%	3,420
Apartment 2004+	71	0.21	0.2%	2,987

*As calculated using SAP methodology with additional BREDEM appliance & cooking use & the 'real ratio' applied

bre

Table 13: Percentage and million tonnes of CO_2 savings per year from base levels by housing stereotype (total saved)

EPISCOPE stereotype: dwelling type and age categories	% and amount of CO2 savings from base (2012) levels							
	S1		S2		S3		S4	
	%	Mt/yr	%	Mt/yr	%	Mt/yr	%	Mt/yr
SFH pre 1919	-35.8%	3.31	-69.7%	6.44	-78.5%	7.25	-95.2%	8.79
SFH 1919-44	-30.6%	1.83	-47.8%	2.86	-59.2%	3.54	-92.5%	5.53
SFH 1945-64	-35.3%	2.35	-54.3%	3.61	-56.5%	3.76	-93.0%	6.19
SFH 1965-80	-40.7%	4.08	-58.7%	5.88	-60.2%	6.03	-94.8%	9.50
SFH 1981-90	-39.0%	1.83	-52.2%	2.45	-54.1%	2.54	-94.8%	4.46
SFH 1991- 2003	-27.1%	1.49	-50.6%	2.78	-52.4%	2.88	-93.5%	5.14
SFH 2004+	-33.1%	0.58	-55.2%	0.97	-56.6%	1.00	-92.7%	1.64
Terraced house pre 1919	-29.3%	6.65	-51.4%	11.65	-64.6%	14.65	-83.9%	19.04
Terraced house 1919-44	-30.0%	5.34	-45.4%	8.08	-55.7%	9.93	-89.7%	15.97
Terraced house 1945-64	-33.6%	5.46	-48.7%	7.90	-53.4%	8.66	-93.2%	15.11
Terraced house 1965-80	-39.7%	4.66	-55.2%	6.48	-57.9%	6.81	-92.7%	10.90
Terraced house 1981-90	-43.7%	1.60	-59.5%	2.19	-62.2%	2.28	-92.8%	3.41
Terraced 1991- 2003	-33.5%	1.10	-51.6%	1.70	-54.2%	1.79	-88.6%	2.92
Terraced house 2004+	-34.9%	0.55	-51.7%	0.81	-54.2%	0.85	-89.7%	1.41
MFH pre 1919	-36.3%	1.82	-55.4%	2.78	-70.4%	3.53	-75.6%	3.79
MFH 1919-44	-32.3%	0.42	-47.8%	0.63	-63.6%	0.83	-81.3%	1.07
MFH 1945-64	-39.6%	1.09	-58.2%	1.60	-63.1%	1.73	-82.6%	2.27
MFH 1965-80	-46.6%	1.75	-70.8%	2.66	-72.3%	2.71	-85.0%	3.19
MFH 1981-90	-52.1%	0.68	-74.7%	0.97	-76.1%	0.99	-84.9%	1.10
MFH 1991- 2003	-51.6%	0.64	-72.8%	0.91	-75.0%	0.93	-82.1%	1.02
MFH 2004+	-50.6%	0.63	-72.5%	0.90	-74.3%	0.92	-81.9%	1.02

Table 13 (cont'd): Percentage and million tonnes per year of CO_2 savings from base levels by housing stereotype (total saved)

EPISCOPE stereotype: dwelling type and age categories	% and amount of CO2 savings from base (2012) levels							
	S1		S2		S3		S4	
	%	Mt/yr	%	Mt/yr	%	Mt/yr	%	Mt/yr
Apartment pre 1919	-31.2%	0.04	-62.1%	0.09	-69.2%	0.10	-69.5%	0.10
Apartment 1919-44	-36.7%	0.04	-57.2%	0.06	-65.9%	0.07	-65.0%	0.07
Apartment 1945-64	-41.1%	0.18	-62.9%	0.27	-68.6%	0.30	-69.5%	0.30
Apartment 1965-80	-52.0%	0.29	-77.2%	0.43	-81.2%	0.45	-77.9%	0.43
Apartment 1981-90	-61.9%	0.03	-93.1%	0.04	-94.1%	0.04	-76.1%	0.03
Apartment 1991- 2003	-51.7%	0.04	-72.3%	0.06	-74.5%	0.06	-69.0%	0.05
Apartment 2004+	-57.9%	0.12	-81.5%	0.17	-83.4%	0.18	-69.4%	0.15

bre

Table 14: Percentage & kg CO_2 saved per year from base levels by stereotype (per household)

EPISCOPE stereotype: dwelling type and age categories (total)	% and amount of CO2 savings from base (2012) levels (per household)							
	S1		S2		S3		S4	
	%	kg/yr	%	kg/yr	%	kg/yr	%	kg/yr
SFH pre 1919	-35.8%	5,857	-69.7%	11,394	-78.5%	12,832	-95.2%	15,558
SFH 1919-44	-30.6%	3,107	-47.8%	4,852	-59.2%	6,003	-92.5%	9,385
SFH 1945-64	-35.3%	3,032	-54.3%	4,669	-56.5%	4,857	-93.0%	8,000
SFH 1965-80	-40.7%	3,193	-58.7%	4,600	-60.2%	4,721	-94.8%	7,435
SFH 1981-90	-39.0%	2,726	-52.2%	3,648	-54.1%	3,782	-94.8%	6,624
SFH 1991- 2003	-27.1%	1,919	-50.6%	3,586	-52.4%	3,714	-93.5%	6,628
SFH 2004+	-33.1%	2,146	-55.2%	3,580	-56.6%	3,667	-92.7%	6,011
Terraced pre 1919	-29.3%	2,321	-51.4%	4,066	-64.6%	5,113	-83.9%	6,642
Terraced 1919-44	-30.0%	1,922	-45.4%	2,911	-55.7%	3,575	-89.7%	5,753
Terraced 1945-64	-33.6%	1,895	-48.7%	2,745	-53.4%	3,006	-93.2%	5,247
Terraced 1965-80	-39.7%	2,104	-55.2%	2,926	-57.9%	3,070	-92.7%	4,919
Terraced 1981-90	-43.7%	2,001	-59.5%	2,727	-62.2%	2,847	-92.8%	4,251
Terraced 1991- 2003	-33.5%	1,443	-51.6%	2,225	-54.2%	2,338	-88.6%	3,821
Terraced 2004+	-34.9%	1,344	-51.7%	1,989	-54.2%	2,087	-89.7%	3,451
MFH pre 1919	-36.3%	2,173	-55.4%	3,317	-70.4%	4,219	-75.6%	4,527
MFH 1919-44	-32.3%	1,426	-47.8%	2,113	-63.6%	2,812	-81.3%	3,595
MFH 1945-64	-39.6%	1,643	-58.2%	2,416	-63.1%	2,615	-82.6%	3,427
MFH 1965-80	-46.6%	1,834	-70.8%	2,786	-72.3%	2,845	-85.0%	3,347
MFH 1981-90	-52.1%	1,754	-74.7%	2,514	-76.1%	2,561	-84.9%	2,857
MFH 1991- 2003	-51.6%	1,746	-72.8%	2,461	-75.0%	2,535	-82.1%	2,776
MFH 2004+	-50.6%	1,539	-72.5%	2,203	-74.3%	2,259	-81.9%	2,491
Apartment pre 1919	-31.2%	2,480	-62.1%	4,932	-69.2%	5,494	-69.5%	5,514
Apartment 1919-44	-36.7%	1,799	-57.2%	2,805	-65.9%	3,230	-65.0%	3,186
Apartment 1945-64	-41.1%	1,692	-62.9%	2,588	-68.6%	2,820	-69.5%	2,857
Apartment 1965-80	-52.0%	2,068	-77.2%	3,070	-81.2%	3,229	-77.9%	3,098
Apartment 1981-90	-61.9%	2,686	-93.1%	4,044	-94.1%	4,085	-76.1%	3,305
Apartment 1991- 2003	-51.7%	1,768	-72.3%	2,474	-74.5%	2,549	-69.0%	2,360
Apartment 2004+	-57.9%	1,729	-81.5%	2,434	-83.4%	2,492	-69.4%	2,073

4 Conclusion and further analysis

4.1 Conclusions

UK Government targets aim to reduce national greenhouse gas emissions (from all uses) by 80% by 2050 when compared to the position in 1990. Progress towards this target has already been made in the housing stock through improvements in energy efficiency in England. The average SAP rating (energy efficiency based on fuel costs) has risen, and CO_2 emissions have fallen. Significant further improvements, however, are required in the housing stock to meet the 2050 targets.

Base modelling of the 2012 EHS data gave total CO_2 emissions to be 124 Mt/year, this equates to 5,652 kg of CO_2 per household per year in England in 2012. The 2050 targets are only achieved by applying the S4 scenario (saving of 87%) which requires a step change in heating systems away from mains gas to electric, along with decarbonisation of the electricity supply. These changes seem likely to require large changes in policies in order to achieve in the relatively short timescale required.

The greatest total saving (in Mt) of CO_2 is seen in the terraced houses, due to their prevalence in the stock. The largest savings per household are seen in the older detached houses, which generally have the largest potential to improve individually, due to their high levels of CO_2 at a base level.

Within the English housing stock it is conceivable to reach a near 100% saturation level of a number of insulation measures (e.g. loft insulation and double glazing). At the present time it is hard to understand from a practical and financial sense how successfully solid wall insulation will penetrate the market as many significant barriers to this exist. A set of scenarios have been run without solid wall insulation, and show that it is not *necessarily* critical to insulate solid walls to meet the 2050 targets.

Market changes will be required in the general heat supply structure. Incentives are likely to be needed to implement the required number of installations of PV, solar water heating and heat pumps required if the 2050 targets are to be met. These changes in installation rates are unlikely to happen quickly enough on their own. Heating systems are likely to naturally improve as they are relatively regularly upgraded and it is possible (and already proven) to implement legislation which requires upgrade to a minimum level (this has already been demonstrated by the successful uptake of condensing boilers over the last 10 years following legislation changes in 2005), however significant changes to the current trends will have to be applied rapidly to implement the large scale switch to heat pumps required in the relatively short timescale to 2050. Barriers to implementation of these technologies include currently the inconvenience and cost to the homeowner, along with a lack of knowledge of the technology.

Additionally, a movement to lower carbon electricity generation on a national scale will be needed to reduce the current electricity carbon factor and make the installation of heat pumps worthwhile.

4.2 Further analysis

Recommendations for future analysis could include:

1. **Further analysis of the existing data, for example:**

   - The consideration of pathways to meet these targets

     - Detailed analysis could be undertaken to understand in more detail the required installations of measures per year and what the required changes to the current trends in energy efficiency improvements would be to meet them.
     - This could be followed with more in depth policy analysis to understand how these pathways could be met.
     - Further analysis of energy supply pathways could be linked in to provide a fuller analysis.

   - Consideration of types of household to target in more detail

     - Further analysis could be undertaken looking at the types of household which would be most likely and feasible to receive the upgrades suggested. This could lead to:
       - Cost analysis
         A key aspect of feasibility would be the cost of measures in the future, and an analysis of this would help improve targeting.
       - Further analysis of suitability of measures for each household
         The detailed nature of the EHS data means that there is a large amount of detailed data available about the nature of the property which could be utilised to future investigate the practical issues involved in some installations.

   - Further analysis of the existing data by fuel type and floor area.

2. **Collection and analysis of further data, for example:**

   - Utilisation of data from existing data such as the Energy Follow Up Survey and current solid wall project could allow for better model inputs and recalculation of the scenario results.

   - Further work to create a 'real' base dataset, where real heating regimes and temperatures are applied to the data and a base file created to replace the 'real ratio' with a better estimate of 'real' energy use in the modelling process.

References

Boardman, B. et al. The 40% House. ECI, 2005. http://www.eci.ox.ac.uk/research/energy/downloads/40house/40house.pdf

BRE, 2014. BRE Building Typology Brochure, England. For EPISCOPE project. http://episcope.eu/fileadmin/tabula/public/docs/brochure/GB_TABULA_TypologyBrochure_BRE.pdf

CCC, 2008. Building a low-carbon economy – the UK's contribution to tackling climate change. The Committee on Climate Change, 2008. *See also subsequent Carbon budgets for reanalysis and revisions.* http://www.theccc.org.uk/publication/building-a-low-carbon-economy-the-uks-contribution-to-tackling-climate-change-2/

DCLG, 2013a. Department of Communities and Local Government, Live Tables on Household Projections. Table 401. https://www.gov.uk/government/statistical-data-sets/live-tables-on-household-projections. Last updated: 9 April 2013.

DCLG, 2013b. Department of Communities and Local Government, English Housing Survey 2011: Homes Report. https://www.gov.uk/government/statistics/english-housing-survey-2011-homes-report. Published July 2013.

DCLG, 2014a. The English Housing Survey. Department of Communities and Local Government, 2014. https://www.gov.uk/government/collections/english-housing-survey

DCLG, 2014b. English Housing Survey Headline Report 2012-13. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/284648/English_Housing_Survey_Headline_Report_2012-13.pdf.

DECC, 2010. 2050 Pathways Analysis: Part 2 - Detailed sectoral trajectories: energy demand-side sectors and other emissions https://econsultation.decc.gov.uk/decc-executive/2050_pathways/supporting_documents/8626DECCPt2DSTsBalancing_1.pdf

DECC, 2013. Department of Energy and Climate Change. Digest of UK Energy Statistics (DUKES) https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes. Last updated July 2013.

DECC, 2014a. UK Greenhouse gas emissions final figures data tables. https://www.gov.uk/government/statistics/final-uk-emissions-estimates. Last updated 25 March 2015.

DECC, 2014b. Valuation of energy use and greenhouse gas emissions for appraisal. Data Table 1. https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal. Last updated: 2 October 2014.

DECC/BRE, 2011. DECC/BRE: The Standard Assessment Procedure for the Energy Rating of Dwellings (SAP). 2009 edition, v9.90. http://www.bre.co.uk/sap2009

HM Government, 2008. The Climate Change Act, 2008. http://www.legislation.gov.uk/ukpga/2008/27/pdfs/ukpga_20080027_en.pdf

HM Government, 2013. The Carbon Plan. Delivering our Low Carbon Future. https://www.gov.uk/government/publications/the-carbon-plan-reducing-greenhouse-gas-emissions--2. Last updated: 29 April 2013

Henderson J. & Hart, J., 2015. BREDEM 2012 – A technical description of the BRE Domestic Energy Model. http://www.bre.co.uk/filelibrary/bredem/BREDEM-2012-specification.pdf. Last updated January 2015.

Hulme, J. et al, 2014. The Energy Follow-Up Survey 2011. DECC / BRE, 2014. https://www.gov.uk/government/publications/energy-follow-up-survey-efus-2011

Shorrock, L. D., Henderson, J. and Utley, J.I. Reducing Carbon emissions from the UK housing stock. BRE, 2005. http://projects.bre.co.uk/PDF_files/ReducingCarbonEmissionsHousingv3.pdf.

Appendix A Detailed tables of CO_2 and energy use

Table A1: Energy use and CO_2 emissions: total

		Water Heating	Space Heating	Lighting	Pumps	Energy-saving technology	Appliances	Cooking	Total (Including appliance and cooking)
base	Energy (TWh/Year)	65.8	291.5	11.9	3.0	-0.6	43.4	10.0	424.9
	CO_2 (Mt/year)	15.0	71.8	6.9	1.7	-0.4	25.2	3.7	124.0
S1	Energy (TWh/Year)	62.5	262.5	12.6	3.2	-0.7	45.9	10.6	396.6
	CO_2 (Mt/year)	13.9	59.3	2.3	0.6	-0.1	8.5	1.7	86.2
S2	Energy (TWh/Year)	59.2	233.7	13.3	3.4	-0.7	48.2	11.1	368.3
	CO_2 (Mt/year)	12.3	49.8	0.5	0.1	0.0	1.7	0.3	64.8
S3	Energy (TWh/Year)	60.2	233.7	10.0	4.7	-36.2	36.1	8.3	316.8
	CO_2 (Mt/year)	12.8	50.3	0.4	0.2	-1.3	1.3	0.3	63.8
S4	Energy (TWh/Year)	35.3	114.3	9.8	4.0	-35.4	35.6	8.2	171.9
	CO_2 (Mt/year)	3.7	11.6	0.4	0.1	-1.3	1.3	0.3	16.0

bre

Table A2: Energy use and CO_2 emissions: per household

		Water Heating	Space Heating	Lighting	Pumps	Energy-saving technology	Appliances	Cooking	Total (Including appliance and cooking)
base	Energy (KWh/Year)	3,000	13,287	544	136	-29	1,977	456	19,371
	CO_2 (Kg/Year)	683	3,274	316	79	-17	1,148	170	5,652
S1	Energy (KWh/Year)	2,035	8,550	412	104	-22	1,496	345	12,919
	CO_2 (Kg/Year)	452	1,933	76	19	-4	278	54	2,808
S2	Energy (KWh/Year)	1,929	7,613	433	112	-22	1,570	361	11,996
	CO_2 (Kg/Year)	401	1,622	16	4	-1	57	11	2,110
S3	Energy (KWh/Year)	1,962	7,612	325	154	-1,178	1,176	270	10,320
	CO_2 (Kg/Year)	416	1,638	12	6	-43	43	8	2,080
S4	Energy (KWh/Year)	1,151	3,722	320	129	-1,152	1,160	267	5,598
	CO_2 (Kg/Year)	120	377	12	5	-42	42	8	521

bre

Appendix B Practical issues of installing solid wall insulation

B1 Background

In the UK, there is significant theoretical potential for improving the energy performance of solid wall housing through solid wall insulation. The current rate of installation of solid wall insulation is low. The reasons for this include financial, technical and also social issues. Factors that affect the true potential for solid wall insulation in the English dwelling stock include:

- Changes to the external appearance of the dwelling
- Changes to the internal floor area of the dwelling
- Occupant conflicts in flats
- Costs
- Disruption/ease of installation

Scenario analyses will typically consider the overall theoretical potential, and seldom take into account the practical difficulties in installing these measures. While this is sometimes deliberate, in that it is often designed to influence policy which may be able to remove these obstacles, in other cases it acts to overstate what can actually be achieved. It is possible, however, using data from the English Housing Survey (EHS) (DCLG, 2014) to quantify the potential for these practical issues to limit the potential for solid wall insulation.

Different practical issues exist with external insulation and internal insulation. External wall insulation systems consist of an insulating layer fixed to the existing wall and a weather protective finish that can either be a wet render system or a dry cladding system. Dry cladding systems can be more aesthetically pleasing than render as different cladding materials can be used. However, they are usually more expensive. External wall insulation can often be installed with minimal disruption to occupants. It can improve the look of aging facades and reduces thermal bridging, therefore minimizing heat loss. However, planning permission may be required and due to the high cost of installing this measure, it can have long payback times.

The following factors are important considerations in estimating the realistic potential for external solid wall insulation:

- In theory, almost all dwellings could be insulated with external wall insulation. Exceptions may include listed dwellings or those in conservation areas, and dwellings in which the walls are structurally unsound.
- Planning permission is usually required as it will change the outside appearance of a dwelling, but facings are available which mimic brick/shipboard etc. Dwellings which are already rendered are unlikely to need additional planning permission.
- The attitudes of homeowners to the application of solid wall insulation to their dwelling is difficult to address. However, it is expected that some homeowners may be averse to changing the external appearance of their dwelling, particularly if it has certain characteristic features that were attractive. Walls with a masonry pointing finish are likely to be most problematic in this regard.
- There is likely to be much less occupant opposition, and fewer problems with planning permission, when applying external wall insulation to the parts of the dwelling as viewed from the rear rather than the front.
- Installing external insulation on a converted or purpose built flat may be problematic as all owners/leaseholder would have to agree to change the external appearance.

- External wall insulation will generally cause less disruption for the occupant than internal wall insulation.

Internal wall insulation can be either a rigid insulation board or insulation fitted between studwork. Disadvantages of both of these internal systems are that they involve considerable disruption for the occupants and can result in a significant decrease in room size. The advantages of internal insulation over external insulation are that it is cheaper and easier to install and maintains the appearance of the external walls.

The following factors are important considerations in estimating the realistic potential for internal wall insulation:

- In theory all dwellings could have internal insulation.
- Depending on the insulation type, between 80 to 120mm of insulation may be required to achieve significant savings. For small houses this would mean a significant decrease in the internal space available.
- Internal insulation could only realistically be applied on a whole-house level if a major internal refurbishment of the dwelling was planned. Alternatively, it could be applied on a room-by-room basis, perhaps as a DIY installation, when rooms were being redecorated.
- Internal insulation could be a better option than external insulation for households living in converted and purpose built flats as it would not involve the whole block of flats to be insulated. However, these dwelling types (along with bungalows) typically have a small floor area (at least 50% of this type have a floor area < $60m^2$) and adding the required thickness of internal insulation could significantly impinge on the available space. It should also be noted that even internal insulation is unlikely to be installed by all occupiers in a block of flats and from an energy efficiency perspective, installing external wall insulation on the whole block would be the preferable option and possibly even more cost effective if carried out on the whole block level.
- Concerns exist that internal insulation may result in negative unintended consequences for some types of building (e.g. condensation problems).

B2 Alternative Scenarios

In light of the current barriers to solid wall insulation, a scenario which did not include this upgrade was undertaken. A revised S4 result, with no solid wall insulation gives total CO_2 emissions of 18.3 Mt/year., a rise of 2.3 Mt per year compared to the original S4 scenario. Energy use is calculated to be 186.1 TWh/year under this new scenario, a rise of 14.2 TWh/year.

The new CO_2 levels equate to a saving of 86% from 1990 levels, still achieving the target 80% drop. The small difference in the total CO_2 emissions compared to the original S4 scenario can be largely attributed to the decarbonisation of the electricity grid and high use of electricity which occurs in scenario S4. All insulation measures installed save much less CO_2 per Kwh compared to the current position where carbon factors are much higher. However, it should be noted that not including solid wall insulation does increase energy use more significantly, and increase the need for greater power supply, thus raising the total UK CO_2 emissions overall.

B3 Barriers to refurbishment identified as part of the UK National Workshop

Summarised below are some of the barriers to refurbishment identified by refurbishment practitioners as part of the UK National Workshop, held as part of the EPISCOPE project at BRE on 10th March 2016. Any views expressed are not necessarily those of BRE.

Responses have been split into four groups: practical, financial, legislative and other barriers.

bre

BARRIERS TO REFURBISHMENT
Practical barriers identified by practitioners:
• Disruption to the household • Difficulty of maintenance or in understanding how to use the technology properly • Skills of installers are insufficient for some technologies • Products can be inefficient to install • Funding schemes can be impractical to administer. • Difficulty installing in all weather conditions • Some technologies are not well known, which leads to practical problems of in installation and maintenance. • Monitoring performance is difficult when tenant turnover is high • Can be difficult to prioritise refurbishment scenarios to maximise benefit for all involved • Mixed tenure flats can prevent whole building approach • Internal solid wall insulation can be (1) Too thick to install practically (2) Disruptions to electrical services internally (3) Undesirable for residents (4) Unattractive • Can be very difficult persuading residents about refurbishment • GSHP/ASHP : reported problems with installation and maintenance
Financial barriers identified by practitioners:
• Lack of funding source, several government funding sources have recently been reduced (Green Deal, CERT, ECO etc.) • Funding will more often go into new build • Cost/benefit of refurbishment may not be sufficient • Housing providers may sell old stock in order to focus on right specification • Funding can be complex to access and time consuming • No benefit in refurbishment for investor, tenant gets all benefits • Difficult to assess where to spend 'properly'/which scenarios to follow • Maintenance costs for some newer technologies higher than a gas boiler. Specialist product engineers rarer/higher cost. • Rent capping/rent restriction will have a major impact (shelving of improvements, replacement of components, lifecycle component work) • No grants for structural/major defects (part funding from other sources would be useful) • Feed-in-tariff funding is now too low to adopt PV • Rent may be unaffordable if rent is simply increased to cover cost
Legislative barriers identified by practitioners:
• Planning barriers e.g. restrictions to Georgian/listed buildings/properties in London ('managed to install secondary glazing but not cost effective) • Consultation requirements of section 20 (leaseholder consultation): (1) Fair cost is disputed (2) Leasholders can nominate own contractors (3) Administrative burden and time constraints (4)can be difficult when it comes to charging (5) Works deemed as improvements can prevent ability to charge leaseholders • Tenancy agreements do not always allow for works to easily undertaken • 'Rent-a-roof' scheme requires too many legal covenants • In the private rented sector: HHSRS not really practical to enforce and energy improvements not seen as necessary in some respects compared to other more basic measures. • Sometimes the wrong type of system may be being installed in order to meet a requirement
Other barriers identified by practitioners:
• High tenant turnover leads to difficulties • Attractiveness to householder not always clear / householders prefer cosmetic changes to kitchen and

bathroom over wall insulation • Can be hard to educate residents/tenants why change is needed • Lack of understanding of the renewable systems. Don't end up saving as much as expected. • Knowledge of housing providers stock can be a problem. Quality of house condition survey data can be poor, with much data out of date. • Not much incentive for home owners (private – owner occupied). If social landlords do the refurbishment, private owners need to get in on the action.
Drivers of refurbishment:
• Fuel poverty • SAP
Tools that would be of assistance to practitioners:
• Some kind of cost benefit analysis tool would be useful in making the case for refurbishment.

Report Ends