element energy

energy saving trust

Review of potential for carbon savings from residential energy efficiency

Final report

for

The Committee on Climate Change

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Contents

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1 Executive Summary

Increasing the energy efficiency of the building stock is an important component of the shift toward a more sustainable energy system. There is a significant potential for abatement of CO_2 emissions through uptake of energy efficiency measures. These include thermal insulation measures which reduce the heating demand, electrical appliances that reduce the electricity consumption and replacement of existing heating and lighting equipment with more efficient technology, often driven by regulations. As well as reducing the level of aggregate emissions, energy efficiency measures can reduce the cost of energy, potentially offsetting any increases required to reduce the carbon intensity of fuel supply. Efficiency measures are often amongst the most cost effective means of carbon reduction.

This study aims to review and update the evidence base on the remaining technical potential for the installation of energy efficiency measures, based on the previous Committee on Climate Change (CCC) work issued in 2011. The energy savings achieved from these measures have been calculated for a range of UK house types using the Standard Assessment Procedure (SAP) calculation methodology for domestic sector. The revised potential and energy savings across the stock are used to generate the marginal abatement cost curves for all measures.

1.1 Key Findings

1.1.1 Technical potential for emission savings

The remaining technical potential in 2013 and the energy savings attributed to each measure result in a total potential for annual emission savings of around **49Mt** (without the inclusion of in use factors). These savings take into account any potential overlap between the impact of measures when applied together e.g. boiler replacement reduces the potential for savings from other thermal fabric measures. It should be noted that these savings do not take into account uptake of low carbon heating technologies such as heat pumps (HP) and combined heat and power (CHP) systems, i.e. these savings are not additional to the emission reduction from a shift of heating technology towards HP and CHP. With a significant uptake of low carbon heating solutions, the potential for additional savings from energy efficiency measures is further reduced.

The technical potential for measures in this analysis takes account of ‘in-use’ factors which are designed to reflect recent evidence on the shortfall of real life savings achieved by measures compared to modelled values. In general, the ‘in use’ factors that are provided by DECC for Green Deal calculations have been used. It should be noted that there is a lack of evidence regarding the in use performance of a wide range of measures and further evidence will be required before it is possible to assess whether the DECC in-use factors applied here accurately reflect the difference between real energy savings and theoretical calculations or whether they are too conservative.

1.1.2 Revisions to cost effectiveness of measures

The revised MACC outputs also show some significant changes to the cost effectiveness (£/tCO_2) relative to the previous CCC MACC model. The most notable difference is for solid wall insulation (SWI), which has a cost effectiveness of £79/t and £361/t for internal and external insulation respectively compared to £9/t in the previous MACC model. This is due to a higher cost of installation and lower energy savings from an overall improvement in stock boiler efficiency. The cost for SWI in the previous MACC model were £6200, however the revised cost evidence shows that these costs vary between £8,500 - £12,000 and £4,000 - £10,500 for external and internal SWI respectively. The energy savings from SWI were previously identified as 9,440kWh /year however with the revised modelling across UK stock, taking into account improved boiler efficiencies, results in weighted average savings of 6,700kWh /year and 6,000kWh /year for external and internal SWI respectively. Costs data in this analysis is based on current market prices where available As such, these prices generally do not take into account potential cost reductions from bulk installations, cost reductions over time etc.

1.1.3 Cost effective measures with good potential for emissions savings

The major cost effective energy efficiency measures include cavity wall insulation (CWI, easy to treat and hard to treat with cavity insulation) and loft insulation (easy to treat 50mm-199mm). The biggest potential for emission savings is represented by SWI (internal and external) and new double glazing (from pre 2002 double glazing) which have combined savings of around **14Mt** (28% of total).

1.2 Measure performance and cost effectiveness across the UK stock

The graphs below show:

1. The technical potential for annual emission savings (Mt) with and without inclusion of the in use factors
2. The annualised cost, fuel savings (£), net cost and annual emission savings (t) for each measure weighted across its total stock
3. Marginal abatement cost curve for all measures without any in use factors

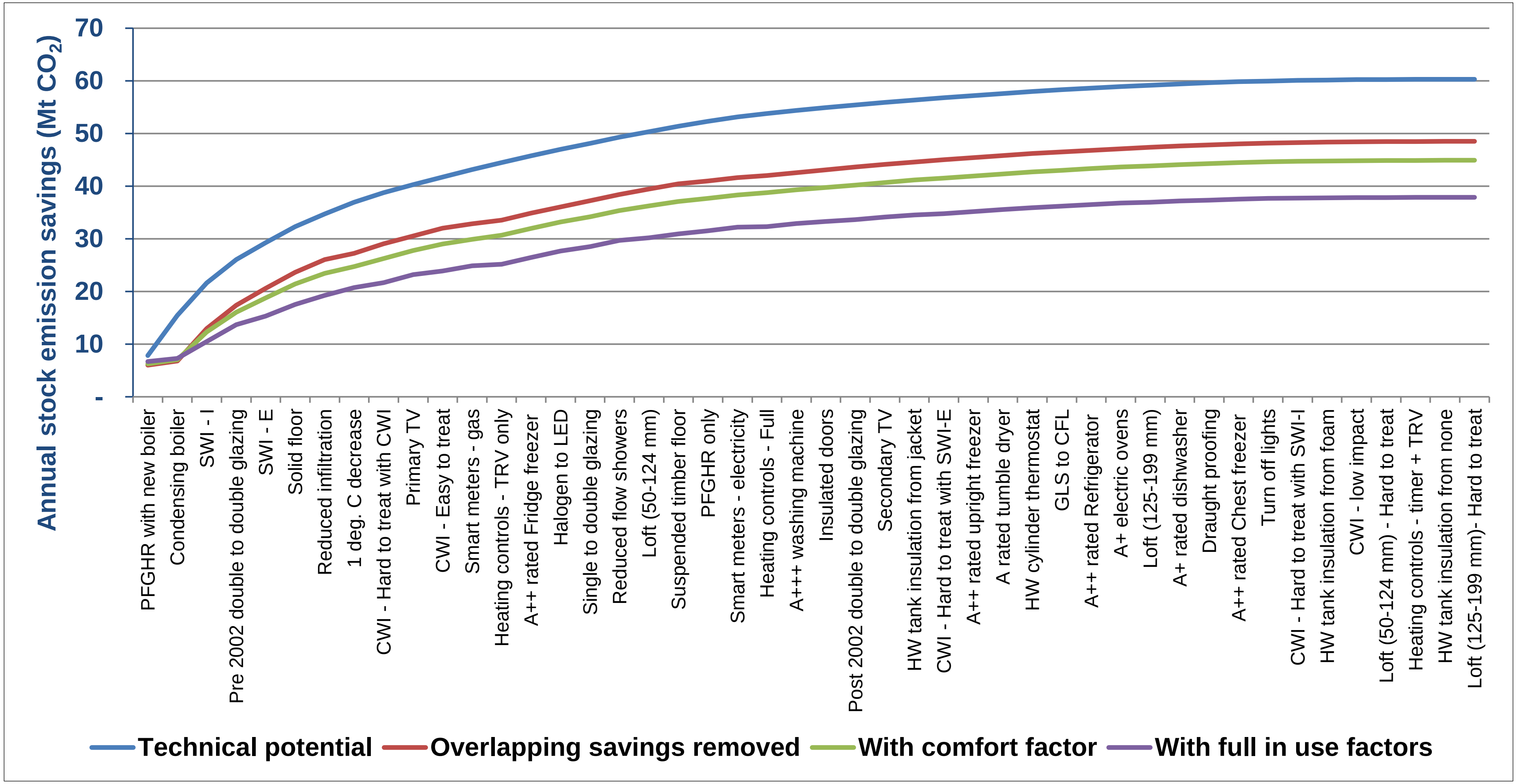


Figure 1 Cumulative potential for emission savings by measures across stock with incremental inclusion of in use factors

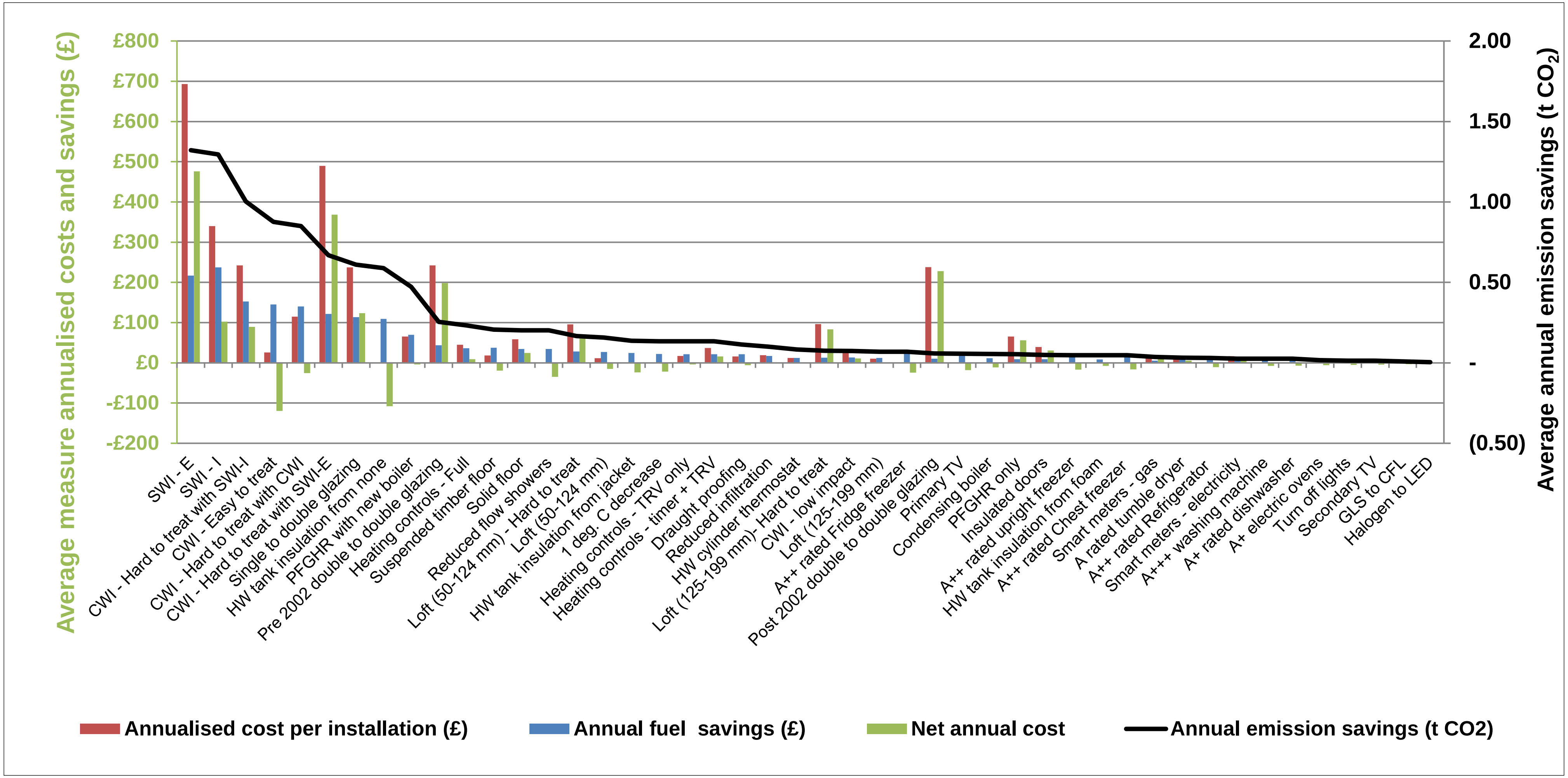


Figure 2 Breakdown of weighted average annualised cost, annual fuel (£) and emission (t CO_2) savings by measure (no IUF applied)

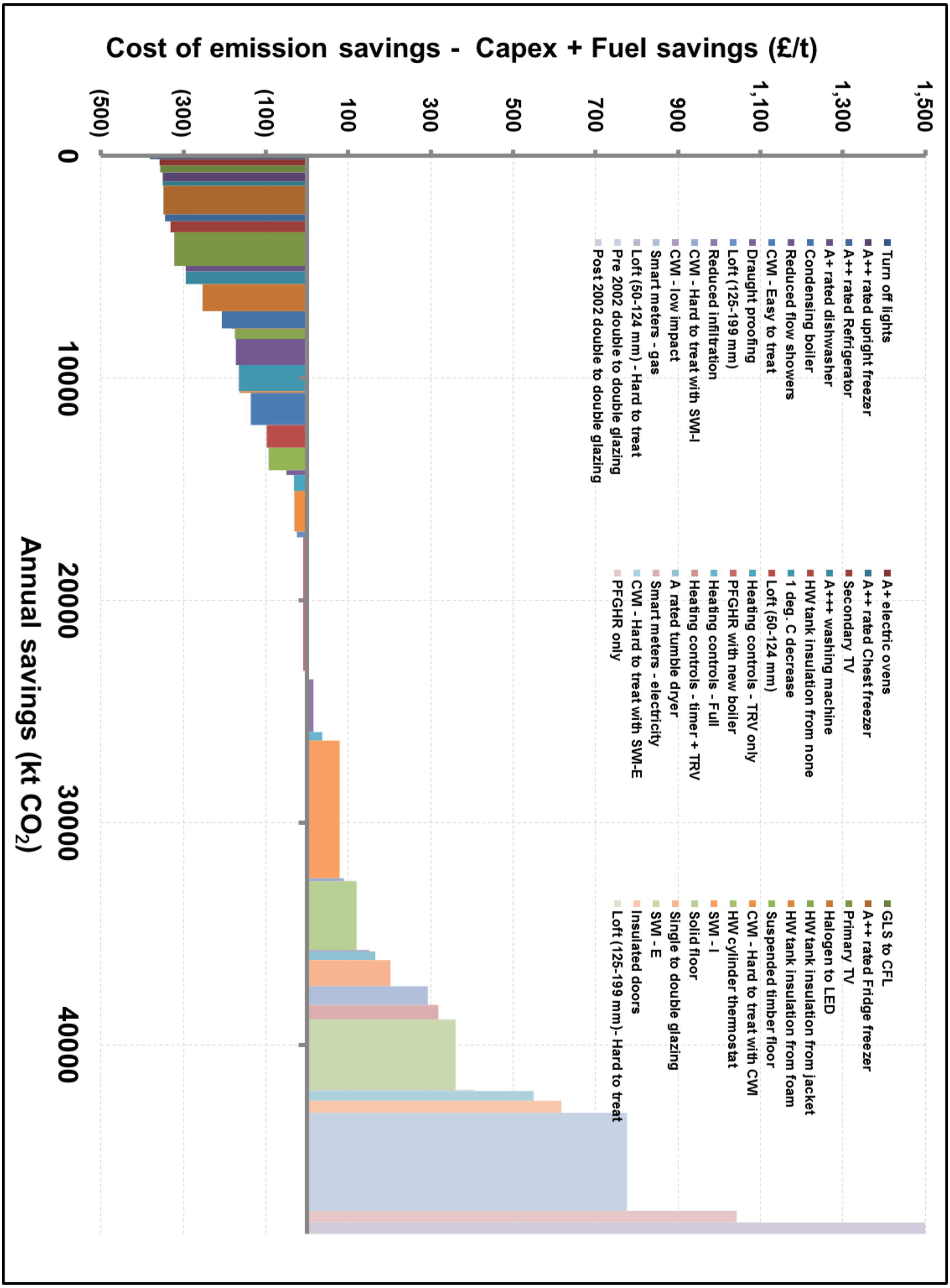


Figure 3 MACC based on total potential without in use factors (overlapping savings removed)

Table 1 Measure technical potential for savings and cost effectiveness without in use factors (overlapping savings removed)

Measure	Total annual savings of UK stock (kt CO_2)	Cost effectiveness (£/t CO_2)
Turn off lights	134	-£381
A+ electric ovens	295	-£357
GLS to CFL	313	-£356
A++ rated upright freezer	400	-£350
A++ rated Chest freezer	195	-£350
A++ rated Fridge freezer	1,290	-£348
A++ rated Refrigerator	308	-£344
Secondary TV	492	-£331
Primary TV	1,516	-£322
A+ rated dishwasher	252	-£294
A+++ washing machine	565	-£294
Halogen to LED	1,218	-£253
Condensing boiler	777	-£206
HW tank insulation from none	16	-£184
HW tank insulation from jacket	458	-£175
Reduced flow showers	1,170	-£172
1 deg. C decrease	1,180	-£165
HW tank insulation from foam	77	-£163
CWI - Easy to treat	1,441	-£136
Loft (50-124 mm)	1,023	-£97
Suspended timber floor	1,012	-£93
Draught proofing	216	-£50
Heating controls - TRV only	718	-£31

CWI - Hard to treat with CWI	1,829	-£30
Loft (125-199 mm)	263	-£24
PFGHR with new boiler	6,001	-£9
HW cylinder thermostat	383	-£5
Reduced infiltration	2,377	£16
Heating controls - Full	381	£37
SWI - I	6,195	£79
CWI - Hard to treat with SWI-I	120	£89
Heating controls - timer + TRV	18	£118
Solid floor	3,091	£121
CWI - low impact	62	£151
A rated tumble dryer	390	£166
Single to double glazing	1,176	£202
Smart meters - gas	841	£294
Smart meters - electricity	654	£319
SWI - E	3,185	£361
Loft (50-124 mm) - Hard to treat	33	£406
CWI - Hard to treat with SWI-E	437	£550
Insulated doors	547	£617
Pre 2002 double to double glazing	4,407	£777
PFGHR only	520	£1,043
Loft (125-199 mm)- Hard to treat	8	£1,101
Post 2002 double to double glazing	510	£3,886

2 Introduction

2.1 Overview

In light of recent evidence on the variation in the installation costs of energy efficiency measures and the actual (rather than modelled) performance of measures the Committee on Climate Change (CCC) wishes to update its earlier work on Marginal Abatement Cost Curves (MACCs) for the residential energy sector. The steps involved in generating the revised MACCs presented in this study were as follows:

1. Review of the technical potential (total installations) for deployment
2. Review of the energy and carbon savings (i.e. technical) potential, noting the issue of overstating savings
3. Updating measure installation costs
4. Calculation of the cost effectiveness (£/t CO_2) of each measure to generate MACC outputs

The report is structured into the following sections:

Methodology for energy modelling

This section provides details around the energy calculation methodology (SAP) and the segmentation of the UK housing stock that has been applied in order to derive the detailed breakdown of energy savings delivered by the installation of each measure across different house types.

Measure performance

This section provides details on the performance improvement delivered by the installation of each of the measures.

Technical potential for energy efficiency measures

This section provides details on the remaining potential for application of each of the measures and how this potential is distributed across the UK housing stock.

In use factors

This section looks at the recent evidence on the underperformance of the measures i.e. the discrepancy between the observed energy savings and those predicted by energy modelling. These reduced savings are a result of consumer behaviour (e.g. comfort-taking), quality of installation and the assumptions around the specification before the installation of the measure.

Measure cost

This section provides a detailed breakdown of the cost of installation of the measures. The cost consists of a fixed and variable component.

The Marginal Abatement Cost Curves (MACC)

This section combines the cost and performance data for each measure to calculate its cost effectiveness (£/t) in delivering emission savings. This allows the MACC to be generated with and without the inclusion of in use factors.

2.2 Methodology

A comprehensive and updated dataset on the fixed and variable cost of residential energy efficiency measure installation has been prepared. These costs, along with data on the attributes of the UK's domestic building stock (wall areas, loft thickness, windows and door areas etc.), can be used to assess the cost of installing these measures in individual house types and the total costs associated with application across the UK housing stock as a whole. Element Energy's Housing Energy Model (HEM)[1] has been used to calculate the energy savings associated with these measures when applied to the various house types within the stock.

The measure installation costs, lifetime fuel and emission savings are then aggregated across the stock for each measure, enabling a calculation of its cost effectiveness (e.g. £/tCO_2). The cost-effectiveness of the measure and the emissions reduction it can deliver when applied across the stock can then be used to generate the Marginal Abatement Cost Curve (MACC).

The process used to derive the residential energy efficiency MACC is shown in the schematic below.

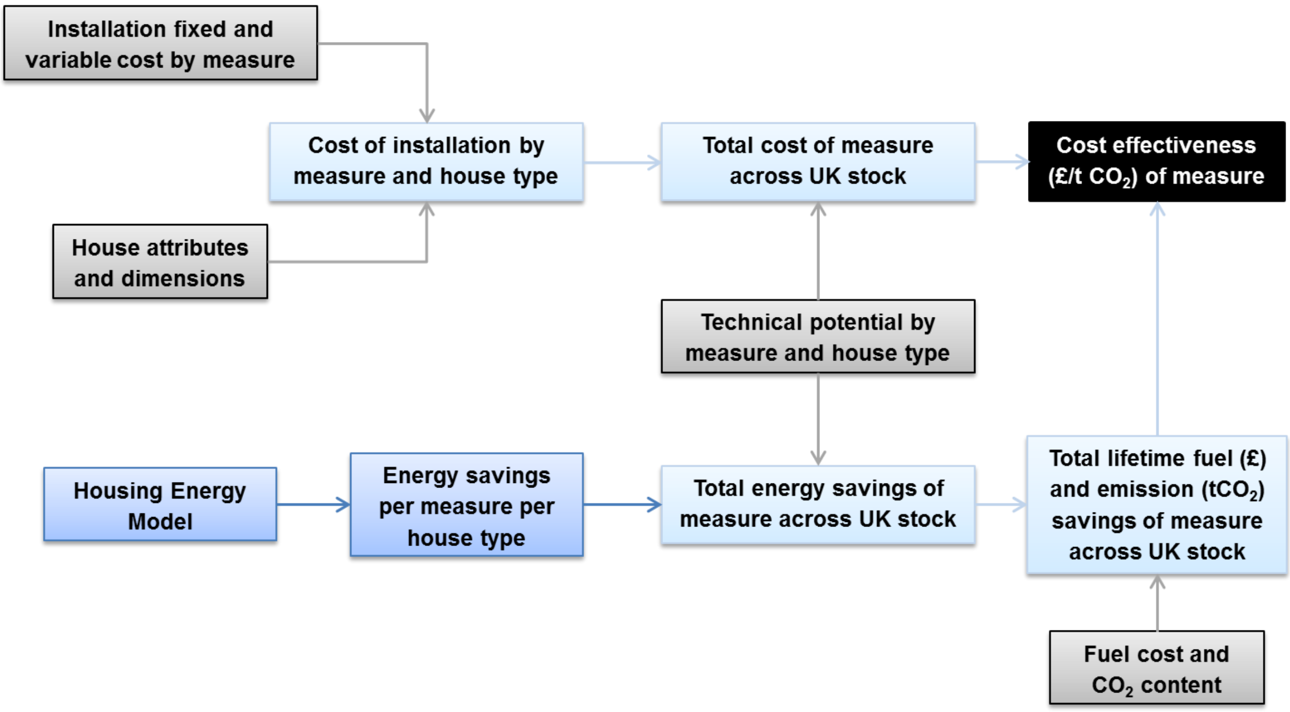


Figure 4 Schematic for calculating MACC

2.3 Measures included in the MACC

The MACC output for the residential sector is generated for thermal measures, energy efficient electrical appliances and behavioural changes. The measures included within the

[1] The Housing Energy Model contains a representation of the UK housing stock based on a set of house archetypes (the 'house types') that have been derived from analysis of the English Housing Condition Survey (see Section 3.2 for a description of the house types). The model calculates the energy consumption of each house type using a calculation methodology based on the Standard Assessment Procedure (SAP).

MACC were initially selected on the basis of consistency with the previous MACC model developed by the CCC. The list of measures was further refined, in consultation with the CCC and on the basis of availability of good quality data on technical availability. The potential for low carbon heating technologies has not been included in the MACC after consultation with CCC. It is important to note that there will be some overlap between the energy and carbon savings included within this MACC with the savings that could be delivered by the uptake of low carbon heating technologies. The measures covered in the review are summarised in the table below:

Table 2 List of measures covered in residential sector

Thermal measures	Appliances	Behavioural changes
Solid wall insulation (SWI) – internal / external	Incandescent light bulb (GLS) to compact fluorescent light (CFL)	1 degree C decrease
Cavity wall insulation (CWI)	Halogen to light emitting diode (LED)	Turn off lights
Loft insulation	A++ rated chest freezer	Smart meters - electricity
Suspended timber floor	A++ rated fridge freezer	Smart meters - gas
Solid floor	A++ rated refrigerator	
Double glazing	A++ rated upright freezer	
Insulated doors	A+++ washing machine	
Draught proofing	A rated tumble dryer	
Reduced infiltration	A+ rated dishwasher	
Condensing boiler	A+ electric ovens	
Heating controls	Primary TV	
Hot water cylinder thermostat	Secondary TV	
Hot water tank insulation	Reduced flow showers	
Passive flue gas heat recovery		

In order to quantify the carbon saving that could be delivered by applying these measures to the housing stock, the remaining potential for each measure needs to be determined (i.e. the number of homes that the measure can be applied to). For certain measures, the level of improvement varies depending on what is present in the house initially. For example the heating controls measure could involve installation of a complete package of heating controls (e.g. thermostat, timer control and TRV) or could involve installation of TRVs only in a home that already has a thermostat and timer control. In these cases the remaining potential of the measure has been further sub-divided into the potential for different levels of upgrade, within the constraints of available data. This is described in detail in Section 5.

3 Methodology for energy modelling

3.1 Overview

Element Energy's Housing Energy Model (HEM) has been used to model the energy savings from the application of the thermal measures. The HEM contains a representation of the UK housing stock based on a set of distinct 'house types'. The definition of the house types, based on data on the UK housing stock is described below. The HEM calculates the annual heating (space and hot water) and regulated electricity (lighting, fans and pumps) demand for each individual house type in the UK stock segmentation using the SAP calculation methodology.

3.2 HEM stock breakdown

The housing stock within HEM is based on a statistical analysis of the English Housing Survey (EHS) to accurately represent the wide variety of different homes in Great Britain. Through a series of trend analyses, the wide variety of variables available in the EHS are filtered to a small set of parameters, allowing the model to distinguish between different house types, whilst maintaining enough granularity to examine trends in different tenure / age / size / heating fuel / wall construction categories.

The final breakdown of the existing GB housing stock used the following distinguishing parameters:

1. Tenure: Owner occupied, private landlord and social
2. Age: Pre-1919, 1919 to 1980 and post-1980
3. Size: Small (flats), medium (bungalows and terraced housing), large (semi and detached housing)
4. Fuel type: Gas, oil, electric, community heating
5. Wall construction: cavity filled, cavity unfilled and solid walls
6. Level of energy efficiency: 'Good' and 'Poor'

The variables included in the 'Good'/'Poor' categorisation are double glazing, heating controls (including Thermostatic Radiator Valves (TRVs), room thermostats and central timers) and hot water cylinder insulation thickness. Using an age and tenure categorisation, the percentage of each category with the energy efficiency measures of 'Good' house type is calculated.

Table 3 Distinguishing properties between 'Good' and 'Poor' homes

'Good' homes	'Poor' homes
Double glazing	Single glazing
Heat controls present	No heating controls (5% less efficient boiler)
Foam hot water cylinder insulation	Jacket hot water cylinder insulation

3.3 SAP calculation

The SAP methodology is applied to calculate the annual heating (space and hot water) and regulated electricity (i.e. without consumer appliances) demand for each individual house type before and after the application of the measure. This gives the detailed breakdown of the energy saving delivered by each measure across the stock segmentation (i.e. the energy saving by measure for each house type that the measure is applicable to).

3.4 Mapping of energy saving onto the technical potential for measures

The technical potential for the installation of each measure is the number of homes that have potential for the measure to be installed (i.e. excluding homes that have already had the measure installed or that are not suitable for the measure). The technical potential has also been disaggregated across a range of house types based on a segmentation of the UK stock. The stock segmentation used to characterise the potential for installation of measures consist of 135 individual house types, based on the following parameters:

1. 3 tenure types: owner occupied, private landlord and social housing
2. 3 sizes: small (flats), medium (bungalows and terraced housing), large (semi and detached housing)
3. 5 fuel types: gas, oil, electric, coal and community heating
4. 3 wall construction types: cavity filled, cavity unfilled and solid walls

This gives a detailed stock segmentation to identify the technical potential of the measures across UK stock. However, due to availability of data, the stock segmentation used to describe the technical potential is based on a reduced set of attributes compared to the more granular stock segmentation used in the HEM. The result of this is that for each house type in the technical potential stock segmentation, there are multiple house types in the HEM with matching attributes of tenure, age, size and fuel (but that are further differentiated by age and good/poor condition). The energy saving associated with each measure for each house type identified within the HEM has been mapped onto the house types used for defining the remaining potential by deriving weighted averages across house types with matching attributes. This results in measure energy savings for each of the house types with a defined technical potential.

The process of mapping energy savings calculated by the HEM onto the stock segmentation used to define the technical potential for the application of measures is illustrated graphically below.

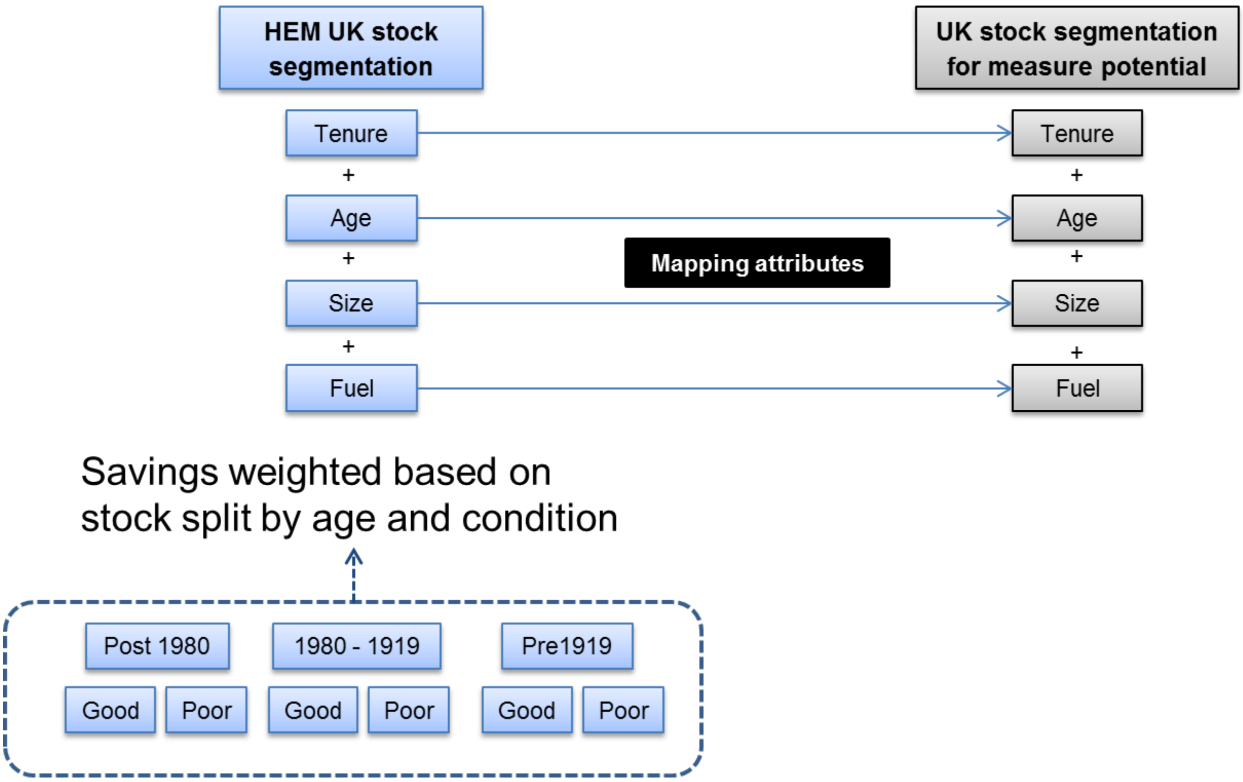
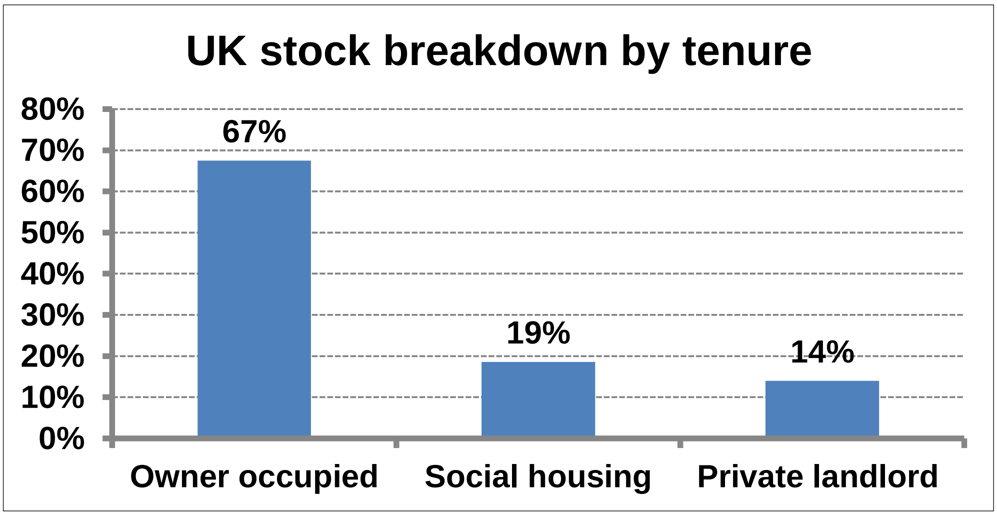
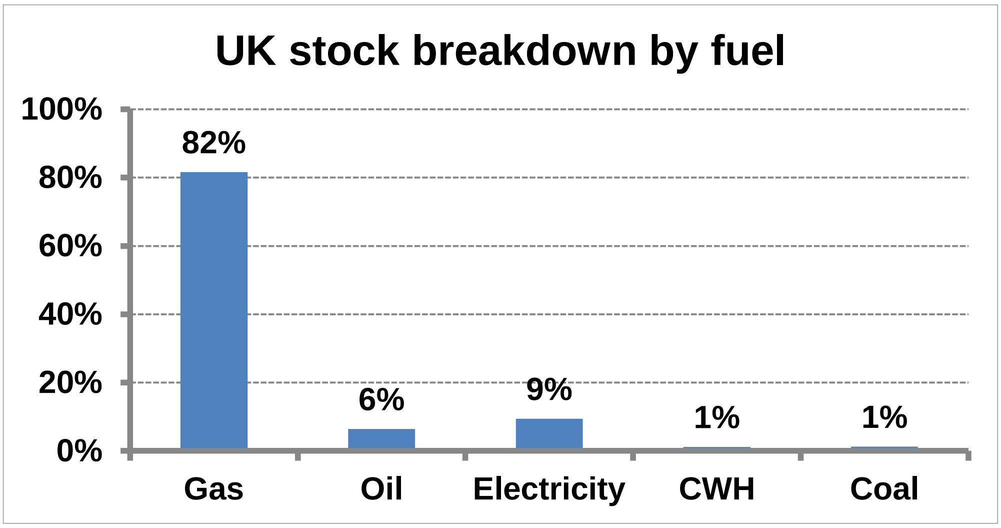


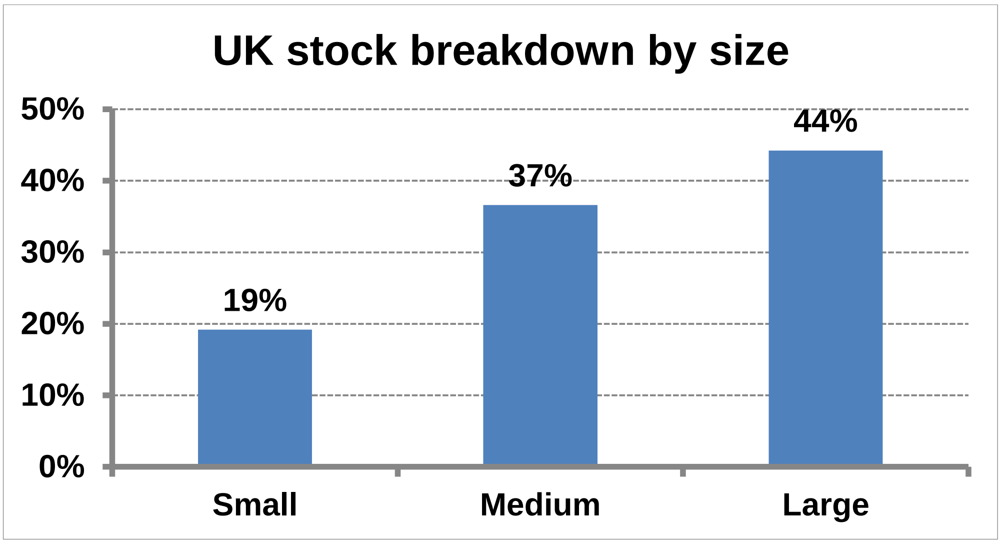
Figure 5 Methodology for generating measure savings across UK stock

3.5 Final UK stock segmentation in MACC model

The MACC model contains the latest UK housing segmentation data, used to identify the technical potential for measures, to define the stock breakdown. This results in the following stock breakdown by attributes:







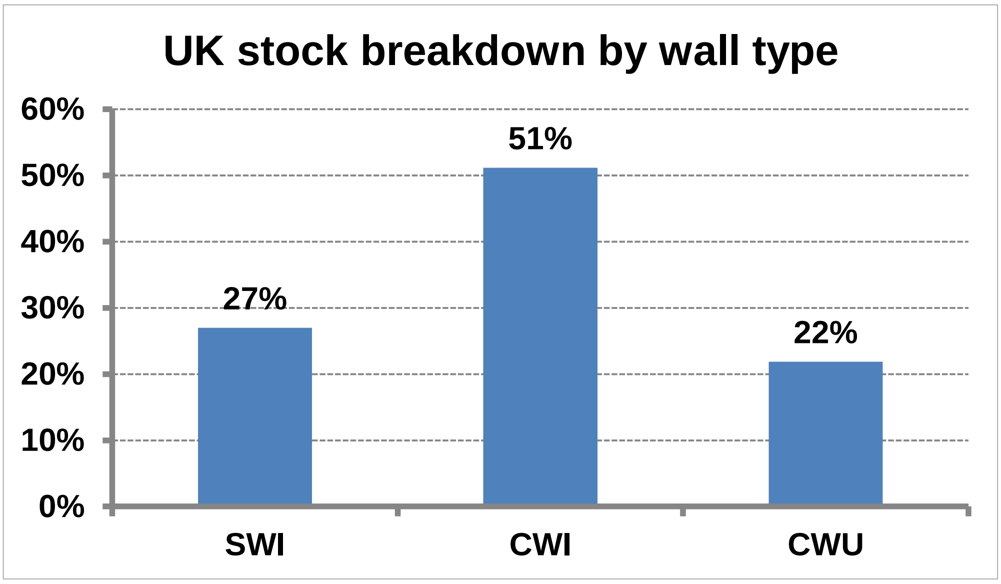


Figure 6 UK stock segmentation for measure potential

4 Measure performance

4.1 Overview

In order to calculate the energy savings associated with application of each of the measures, technical specifications are required for the improvement in the performance of the relevant components of the house, e.g. the fabric U-values, boiler efficiency etc.. The technical specification and performance of all thermal and electrical appliance measures has been updated based on the latest building regulations, data on appliances in the stock and on the highest energy rated products on the market. These specifications allow the energy demand before and after the installation of measure to be calculated, resulting in the calculation of the modelled savings.

4.2 Technical specifications of the measures

The detailed breakdown of the performance of the measures is shown in the table below. The performance of some of the measures differ based on age, size and loft thickness.

Table 4 Detailed technical specifications of thermal measures and appliances

Measure		Parameter	Specification	
			Baseline	Measure
SWI internal/external	Post 1980	U value (W/m^{2}K)	0.500	0.300
	1919-1980		1.822	0.300
	Pre 1919		2.200	0.300
CWI low impact	Post 1980		0.464	0.360
	1919-1980		0.464	0.360
	Pre 1919		0.464	0.360
CWI high impact	Post 1980		0.508	0.508
	1919-1980		1.683	0.547
	Pre 1919		2.149	0.556
Loft insulation	0-50 mm		1.70	0.150
	51-125 mm		0.434	0.150
	126-200 mm		0.270	0.150
Solid / suspended timber	Post 1980		0.45	0.22
	1919-1980 (Large)		0.76	0.22
	1919-1980 (Medium)		0.53	0.22
	1919-1980 (Small)		0.45	0.22
	Pre 1919 (Large)		0.68	0.22
	Pre 1919 (Medium)		0.52	0.22
	Pre 1919 (Small)		0.44	0.22
Double glazing	From single		4.8	1.6
	From pre 2002 double		3.1	1.6
	From post 2002 double		2	1.6
Insulated doors			3	1.8
Draught proofing		Fraction of windows / doors	0%	100%
Reduced infiltration		m^3/m^{2}hr	8-18	7
Condensing boiler	Gas	Efficiency	75%	88%
	Oil		84%	88%
Heating controls	Thermostat+ timer +TRV	Control type / Temperature variation	1/+0.6C	2/+0.0C
	Timer +TRV		1/+0.0C	2/+0.0C
	TRV only		1/+0.0C	2/+0.0C
Hot water cylinder thermostat	Large	kWh reduction		500
	Medium			590
	Small			570

Hot water cylinder jacket insulation	No insulation	Thickness (mm)	0	80
	Jacket insulation		24	80
	Foam insulation		15	80
Passive flue gas heat recovery	Condensing boiler	Efficiency	88%	91%
	Non condensing gas boiler		75%	91%
1 degree decrease		Target internal temperature	18C	17C
GLS to CFL	Electricity	Reduction		83%
	Heating	Gain		60%
Halogen to LED	Electricity	Reduction		77%
	Heating	Gain		55%
Turning off lights		Reduction		10%
Smart meter	Electricity	Reduction		2.8%
	Gas			1.8%
A++ rated Chest freezer		Electricity kWh reduction / Heating kWh gain		178 / 101
A++ rated Fridge freezer				265 / 150
A++ rated Refrigerator				116 / 66
A++ rated upright freezer				182 / 103
A+++ washing machine				70 / 2
A rated tumble dryer				85 / 2
A+ rated dishwasher				67 / 2
A+ electric ovens				66 / 40
Primary TV				220 / 132
Secondary TV				54 / 32
Reduced flow showers				0/-968

The specific data sources used to determine the technical specification of each of the measures are referenced in the table below.

Table 5 Reference for specification of measures before and after installation

Measure	**Reference**	
	Baseline	**With measure**
SWI	Post 1980: Average of ages[2] G to J for top three solid wall constructions	As in Building Regulations Part L1B - Existing dwellings (2010)
	1919-1980: Average of ages C to F and half of B for three top solid wall constructions	
	Pre 1919: Average of ages A and B for top three solid wall constructions	
CWI – low impact	From In-built 2012 DECC report, same for all ages	From In-built 2012 DECC report, same for all ages
CWI – high impact	Based on values calibrated from the initial U-values available in	Weighted average of low cost (39%) and high cost (61%) high

[2] SAP age band: A (pre 1900), B (1900-1929), B (1900-1929), C (1930-1949), D (1950-1966), E (1967-1975), F (1976-1982), G (1983-1990), H (1991-1995), I (1996-2002), J (2003-2006)

	SAP corresponding to the whole CWU stock (Post 1980: 0.5; 1919-1980: 1.467; Pre-1919: 1.85), the initial U-values for low impact CWU, and the stock corresponding to low impact (18%) and high impact (82%) cavity walls	impact CWU Breakdown of low cost high impact by age is: Post 1980: Average of ages G, H, I and J for 'filled cavity' 1919-1980: Average of ages C, D, E, F and half of age B for 'filled cavity' row Pre 1919: Average for age A and half of age B in the 'filled cavity' row High cost high impact is derived from In-build 2012 DECC report, same for all ages
Loft insulation	Based on the initial average thickness of loft insulation	As in Building Regulations Part L1B - Existing dwellings (2010)
Solid / suspended timber	Based on standard SAP values	
Door insulation		
Solid floor		
Reduced infiltration	Based on standard SAP values	Energy Saving Trust (2005) GPG 224 Improving airtightness in dwellings
Condensing boiler	Heating and Hot water Industry Council	SEDBUK 2009
Heating controls	Based on standard SAP values	
Hot water cylinder thermostat	BREDEM modelling 2009	
Hot water cylinder insulation	Average thickness across the stock	Standard jacket insulation
Passive flue gas heat recovery	Vaillant recoFLUE	
1 degree decrease	Based on standard SAP values	
GLS to CFL	Domestic Lighting Government Standards Evidence Base 2009	
Halogen to LED		
Turning off lights	Environmental Change Unit, University of Oxford, 1997	

<table>
<tr><td>Smart meter</td><td colspan="2">Smart meter roll-out for the non-domestic sector (GB) – Impact Assessment, DECC 2012</td></tr>
<tr><td>A++ rated chest freezer</td><td rowspan="9">EU energy label calculations for appliances by energy band</td><td rowspan="9">EU energy label calculations for A++ rated appliances and heat replacement effects based on Defra’s Market Transformation Programme</td></tr>
<tr><td>A++ rated fridge freezer</td></tr>
<tr><td>A++ rated refrigerator</td></tr>
<tr><td>A++ rated upright freezer</td></tr>
<tr><td>A+++ washing machine</td></tr>
<tr><td>A rated tumble dryer</td></tr>
<tr><td>A+ rated dishwasher</td></tr>
<tr><td>Primary TV</td></tr>
<tr><td>Secondary TV</td></tr>
<tr><td>Reduced flow showers</td><td colspan="2">Defra (2009) Market Transformation Programme What if tool</td></tr>
</table>

4.3 Energy savings across the stock

The HEM provides a calculation of the energy saving associated with each of the thermal measures that varies across the house types based on their size, tenure and fuel (to reflect the efficiency of the counterfactual heating system). The savings form the electrical appliances are based on the EU energy label calculations for appliances by energy band. In parallel with the reduced electricity consumption, more efficient appliances also result in an uplift in heating demand (i.e. negative heating fuel savings) due to lower internal gains. The resulting average savings by measure, weighted based on the stock of different house types (i.e. total stock energy savings divided by total identified potential), are shown in the chart below:

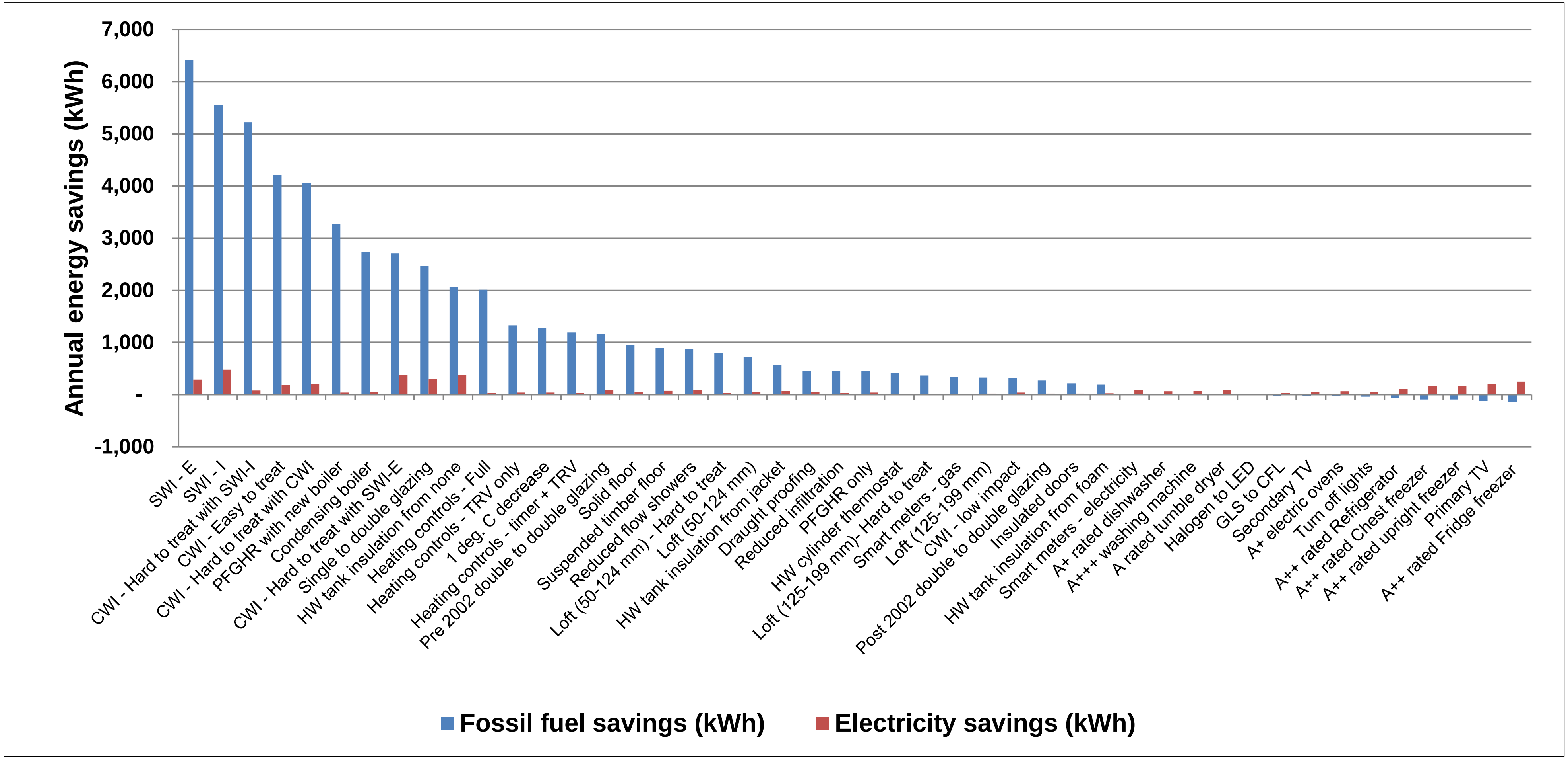


Figure 7 Breakdown of weighted average fossil fuel and electricity savings

5 Technical potential for energy efficiency measures

5.1 Overview

The data on the technical potential for energy efficiency measures in the UK housing stock was developed by the Energy Saving Trust (EST) by synthesising a variety of existing data sources as outlined in the methodology statements below. Summary tables are provided at the UK wide level for each measure type below. For the MACC and trajectory analysis, the potential for each measure was calculated for each of the 135 housing archetypes described in Section 3.2.

In calculating the potential for wall type, loft insulation, boiler type, glazing type, heating controls, energy efficient doors, hot water cylinder thermostat and hot water cylinder insulation, EST adopted an outline methodology based on that used by DECC in the calculation of the Quarterly Insulation Potential (QIP) updates[3] as illustrated in Figure 5. This methodology was chosen as it was deemed suitable and would better enable the CCC to monitor progress reported in the (QIP) against the trajectories over time.

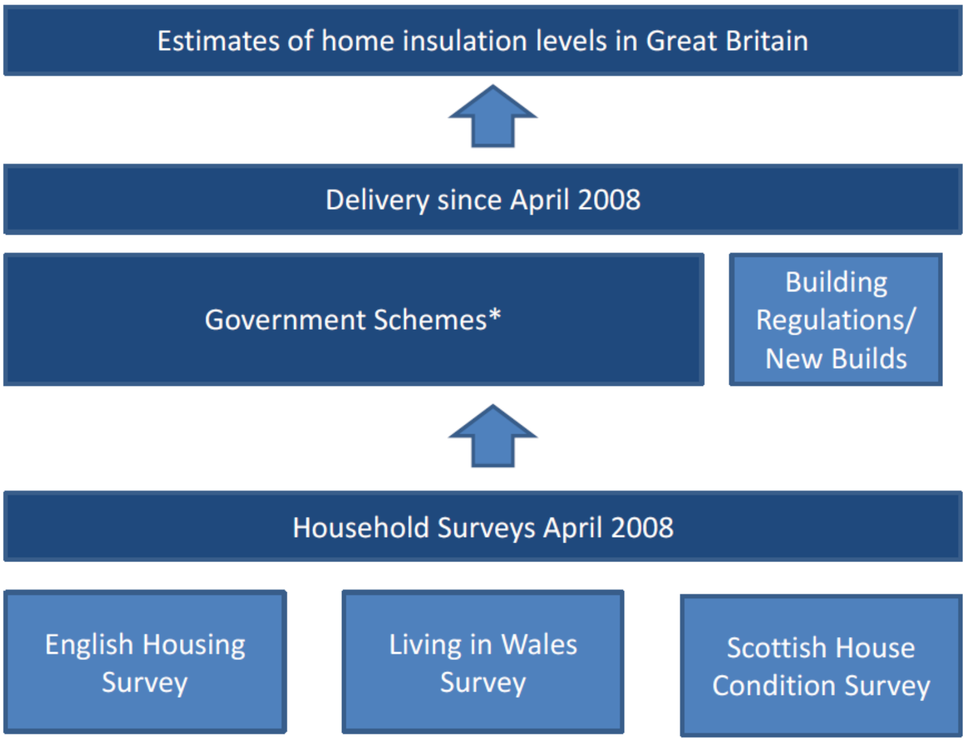


Figure 8 DECC Methodology to calculate measure potential

The English Housing Survey (EHS) 2008, Scottish House Condition Survey (SHCS) 2008 and Living in Wales (LiW) survey 2008 were combined to create a master survey record file of 21,907 survey records. The 2008 housing surveys were chosen instead of more recent housing survey data available as:

[3] https://www.gov.uk/government/statistical-data-sets/estimates-of-home-insulation-levels-in-great-britain

- The surveys allow for a consistent dataset across all countries (the most recent survey for Wales is 2008)
- There is good quality data on the level of installation activity Post 2008, therefore using a 2008 baseline enables more 'actual' data to be factored in the data as opposed to survey records

The Northern Ireland Housing Survey was not available at the address level for inclusion in the UK survey dataset however summarised results from this study were available from the Northern Ireland Housing Survey Report 2011. These results were added at a later stage of the process.

In some cases the different housing surveys contain different categorisations of house type and measure categories. Where this was the case these were mapped to the nearest equivalent category to provide a common format. The classifications of the English Housing Survey were used as that is the largest survey.

Differences to the DECC Quarterly Insulation Potential estimates

Although the methodology described by DECC was followed where possible, it should be noted that in certain cases this methodology was deemed to be inaccurate or it was not possible for EST to follow it completely therefore the results do not always mirror DECC's estimates of measure potential in the QIP. This difference is notable in the case of the split between *hard to treat* and *easy to treat* cavity walls where the DECC methodology appears to double count a number of hard to treat cavity wall figures, thereby over-estimating the number of hard to treat cavity walls at the expense of easy to treat cavity walls. Details are given in this report where these methods diverge and detailed description of the differences between the DECC and EST estimates is provided in the appendix.

5.1.1 Wall Insulation Potential

Figure 5 gives an overview of the methodology used by EST to calculate the current wall types and insulation levels of the UK housing stock in 2013.

In order to calculate the total stock of the different categories of hard to treat cavity walls, EST followed the definitions described in the Inbuilt 2012 report on hard to treat cavity walls which was used as the source of the DECC estimates of hard to treat cavity wall numbers. This methodology was based on extracting relevant data from the 2008 EHS, SHCS and Living in Wales Surveys and is described in detail below.

The results of the wall type potentials analysis are provided in the table below:

Wall type	Description	Potential (taking in to account overlap between categories)	Stock (%)
Solid walls	Solid Wall (un-insulated)	7,194,436	26%
	Solid wall (insulated)	209,000	1%
Insulated Cavities or equivalent U-value	Insulated cavities (+ 5% Pre 1990 Un-insulated)	13,342,659	48%
	Insulated or equivalent (Post 1990)	1,365,700	5%
Empty cavities with limited potential for improvement	Standard cavities with Limited potential for improvement 1980 - 1990 (easy to treat)	838,920	3%
	Hard to treat cavities with Limited potential for improvement (1980 – 1990) plus un-insulatable timber frame dwellings with insulation between the studwork	369,881	1%
Standard empty cavities	Not insulated Easy to treat	1,644,482	6%
	Total Hard to Treat cavities*	2,924,923	10%
Hard to fill empty cavities	Hard to treat: Narrow	474,989	2%
	Hard to treat: Concrete frame	524,889	2%
	Hard to treat Metal Frame	62,888	0%
	Hard to treat Timber frame (un-insulated studwork with masonry cavity)	65,483	0%
	Hard to treat: Wall fault	1,386,191	5%
	Hard to treat: Too high (greater than 3 stories)	91,091	0%
	Hard to treat: Exposed Location	199,953	1%
	Hard to treat: Random stone	119,438	0%
	Total	27,890,000	100%

Figure 9 Detailed breakdown of wall type potential

*A large number of hard to treat cavities in the GB Housing Surveys could fit in to two or more of the above categories. Where a home could fit in to two or more categories, in certain cases it was possible to assign a proportion of a property weighting to each. Where this was not the case, a property was assigned to a unique category according to a hierarchy which is outlined in the appendix.

The majority of homes (84% in the EHS) are constructed entirely using the same form of wall. For properties with mixed wall types, on average there was a clearly identifiable predominant wall type. On average, for these properties 75% of the wall area was constructed with the same kind of wall. For this reason the predominant wall type in the EHS, SCHS, LiW and NIHCS was chosen as representative of the whole property's wall type.

Insulated + 5% uncertainty
This category includes all properties listed as insulated cavity in the housing survey plus 5% of all pre-1990 properties listed as un-insulated cavity walls. BRE suggest that the

housing surveys may underestimate the number of insulated cavity walls by 5 – 10% due to the difficulties in identifying retrofit and in-situ cavity wall insulation. Only the first 5% of this uncertainty has been included here because a typical cause of surveyors not identifying cavity wall insulation, cited by BRE, is where the insulation is built in to the cavity wall rather than retrofitted in which case it is harder for a surveyor to identify the insulation. The vast majority of these instances will be in post 1980 homes which are now considered separately in the 'insulated or equivalent' and 'limited potential' categories. It was therefore assumed that 5% was sufficient to account for the non-identification of cavity wall insulation by surveyors. The number of cavity wall installations post April 2007 was sourced from the DECC QIP data. In addition, all new build dwellings post April 2008 were added to this category, the numbers of which were sourced from the DECC QIP.

Insulated or equivalent
All properties constructed after 1990 are assumed to have a wall with a U value of 0.45 or better. Any properties listed as having un-insulated cavity walls, or other wall types in this age band have been classified as equivalent to an insulated wall. This category differs from the DECC methodology in that DECC assume that all properties Post 1995 are Insulated or Equivalent. However, the post 1995 age band is not in the EHS 2008 housing survey and so it is unclear how DECC was able to apply this assumption. It was felt that assuming all post 1990 cavities are insulated or equivalent was the closest equivalent assumption that could be made.

Limited potential – easy to treat
This category includes all un-insulated cavities, which do not meet a definition of hard to treat, constructed between 1981 – 1990 (1983 and 1990 in Scotland).

All cavities built between 1981 and 1990 (1983 and 1990 in Scotland) are assumed to have a U-value of 0.6, whether the cavity is insulated or not. Although there will be additional savings from insulating the cavity, these savings are small compared to pre 1980 properties.

In the DECC methodology, this category includes all cavities between 1983 and 1995. Again, because this age band is not included in the EHS 2008 we are unclear how the DECC figure was derived and using the 1981- 1990 age band was the nearest equivalent assumption.

Limited potential – hard to treat
This category includes all timber frame properties with a masonry cavity where insulation is included between the studwork but not in the cavity wall. In addition, this category contains all other definitions of hard to treat cavity that sit within the 1981 – 1990 age band (1983 – 1990 in Scotland) including narrow cavities, concrete frames, metal frames, timber frames, random stone, too tall and exposed cavities. The DECC methodology also includes partial fill cavity walls in this category. In the EST data these are included in the Insulated cavity column as it is not possible to identify them from the EHS data.

Not insulated – easy to treat
All pre 1980 properties listed in the housing survey as having un-insulated cavity walls minus all properties that meet the definitions of hard to treat cavities below.

Hard to treat – narrow cavity
All empty cavities 1920 – 1945 are assumed to have a 20% likelihood of having a cavity narrower than 50mm. All un-insulated cavity walls constructed between 1945 and 1990 are assumed to have a 5% likelihood of having a cavity narrower than 50mm. There is a large overlap between properties identified as narrow cavity and properties listed as having wall faults (approximately 120,000 dwellings according to the housing surveys). Where this overlap occurs, narrow cavity was listed as the primary value.

Hard to treat concrete frame
All properties listed as being un-insulated with concrete construction, excluding in-situ concrete and crosswall construction. A large number of concrete frame properties are also

listed as being greater than 3 stories (approximately 150,000 according to the housing surveys). Where this overlap occurs, Concrete frame was listed as the primary value.

Hard to treat – metal construction
All properties listed as being of metal construction with no insulation. There are a significant number of properties with metal frames listed as being greater than 3 stories. Where this overlap occurs, Metal frame was listed as the primary value.

Hard to treat – timber frame (un-insulated studwork plus a masonry cavity)
All pre 1980 properties listed as being of timber frame construction with a masonry cavity and no evidence of having either insulated studwork or cavity.

Hard to treat – random stone
All non-urban non-flat properties in Scotland built before 1980 without solid walls but with walls constructed from whin/granite or sandstone are classified as random stone construction. 25% of English un-insulated masonry construction properties built before 1980 that are not in an urban location and identified as not having solid walls are assumed to have random stone walls.

Hard to treat – exposed
DECC assume that 225,000 standard cavity walls are in exposed locations. This equates to approximately 4% of all pre-1990 un-insulated standard cavity walls. Given that exposure data is not available in the housing surveys it has been assumed that 4% of all standard un-insulated cavities are in exposed locations.

Hard to treat – wall fault
Any pre 1980 properties with un-insulated cavity walls listed in the English or Welsh surveys as having a wall fault, or any Scottish properties reported as requiring urgent repair to the wall finish or having evidence of penetrating damp.

Hard to treat – too high
All pre 1980 properties listed as having un-insulated cavity walls and being greater than 3 stories in height. Properties in the Scottish housing survey are recorded as having 3 stories or more. It is assumed that 50% of these properties are more than 3 stories. Please note that the DECC estimates of Hard to treat cavities – too high are based on a definition of being greater than 4 stories in height. This is an older definition that does not reflect the Ofgem definition of a hard to treat cavity under ECO. Therefore, in this analysis there is a much larger number of properties listed as being too tall in the housing surveys, however, a large number of these are also listed as being concrete or metal frame of having a wall fault. Where this overlap occurs, the properties are listed as either concrete frame, metal frame or wall fault rather than being listed as too high. Ignoring all of the overlaps, there are approximately 419,000 properties listed as being too high in the GB housing surveys.

Internal vs External Wall Insulation potential

All properties listed as having solid walls in the housing surveys (solid brick, solid stone or in-situ concrete without masonry pointing) are assumed to be suitable for either internal or external solid wall insulation. In theory, any type of solid wall could be suitable for either internal wall or external wall. To inform the MACC and uptake analysis undertaken by Element Energy, it was necessary to develop estimates of the potential for internal wall and external wall insulation. In this analysis we have assumed that all properties suitable for solid wall insulation built before 1919 are suitable for internal wall insulation as opposed to external wall insulation. This assumes that households in homes built before 1919 would be more inclined to install internal rather than external wall insulation so as to preserve the outside appearance of the home. In reality this distinction is unlikely to be as clear cut. Savings from internal and external wall insulation are similar as both measures result in external walls having a similar U-value while the costs are higher for external insulation.

5.1.2 Loft insulation

The DECC Methodology outlined in Figure 5 was used to calculate loft insulation potential. Using the combined GB housing surveys, homes were categorised as having one of four loft insulation levels or no loft:

1. 0-49mm
2. 50 -124mm
3. 125-199mm
4. 200mm+
5. No loft

This assumes that all types of roof insulation have the same insulation properties. Each of these categories was further split into easy to treat and hard to treat lofts. DECC classify all hard to treat lofts as "properties that contain lofts which are hard to insulate. For example properties with a flat roof or very shallow pitch (to make the loft space inaccessible". For this analysis all roofs classified in the GB housing surveys as having a mansard roof, chalet roof, flat roof or mono-pitch roof are classified as hard to treat. Flat roofs by definition do not have a loft space; mansard roofs do have a roof space but it is usually shallow and therefore difficult to access. Chalet roofs may have some roof space that can be insulated however this level of detail is not reported in any of the housing surveys. No properties built after 1990 are assumed to have hard to treat lofts, as it is assumed that these dwellings have sufficient insulation in accordance with building regulations.

Data on the number of loft insulation since April 2008 was taken from the DECC QIP. EST was able to provide representative data of how these installations were applied across the stock with data from the Homes Energy Efficiency Database (HEED).

In determining the proportion of loft insulation that was installed in to virgin lofts vs lofts that only required top up insulation, EST was able to draw on CERT installations data in HEED which contains information on the before and after levels of loft insulation for CERT measures. This is only available for professionally installed loft insulation, not DIY insulation. It should be noted that, even though the figures were available for professional installation only, there were more installations reported in 0 – 50mm lofts than there were 0 – 50mm lofts available for insulation according to the combined GB 2008 housing surveys. This highlights the inherent uncertainties in the survey based data. For this analysis, it was assumed that the technical potential for 0 – 50mm lofts is now zero, although in practice it is likely that a number do still exist.

The results of the loft insulation potential analysis are provided below:

Loft type	Thickness	Potential	Stock (%)
Easy to treat lofts	0-49mm	0	0%
	50 - 124mm	6,539,108	23%
	125 - 199mm	3,780,099	14%
	200mm+	13,028,024	47%
Hard to treat lofts	0-49mm HTT	25,889	0%
	50 - 124mm HTT	201,688	1%
	125 - 199mm HTT	111,073	0%
	200mm+ HTT	114,640	0%
No potential	Non suitable for insulation / No loft	4,089,479	15%
	Total	**27,890,000**	**100%**

These numbers are closely aligned with the DECC estimates of insulation potential for April 2013 which are provided below.

Start of:	Insulated >=125mm	Uncertainty	Remaining potential		Properties with a loft
			Easy to treat	Hard to treat	
Apr-2013	16,160,000	100,000	5,740,000	1,700,000	23,690,000

5.1.3 Floor insulation

Insulation for floors is split into two categories of suspended timber floor insulation and solid floor insulation. It is assumed that no floors have been insulated since the 2008 housing surveys and that all new builds 2008 – 2013 have fully insulated floors. The English Housing Survey contains data on floors that have insulation, however no data exists in any of the housing surveys as to the construction type of the ground floor and for this reason the age of the property was used as a proxy for the floor type. All homes built before 1929 are assumed to have suspended timber floors whereas all built in subsequent years are assumed to have solid floors. This follows the assumptions used in RdSAP 2009 (See appendix S table S 11 of the SAP 2009 document)[4]. The proportion of floors insulated in the EHS pre 1929 was taken to be representative of the UK as a whole. The results of the floor insulation potentials analysis are provided below:

Floor Insulation	Potential	Stock (%)
Suspended timber floor insulation potential	4,896,737	18%
Solid floor insulation potential	15,272,980	55%
Insulated floor / no potential	7,720,284	28%
Total	27,890,000	100%

[4] http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf

5.1.4 Double glazing

A similar methodology as outlined in figure 5 was used to calculate different types of glazing in the housing stock. All homes in EHS, SHCS and LiW were placed into three glazing categories; those having either predominantly single glazing, double glazing installed before 2002 or double glazing installed after 2002. In 2002 England and Wales building regulations were enforced, specifying that any new or replacement window must have a minimum Window Energy Rating (WER) of C or above. All surveys contain data on single vs. double glazing. Many homes have multiple types of windows (approx. 25% of EHS homes), for these the predominant type of glazing was used as representative of the whole home.

EHS and LiW contain data on the age of the double glazing enabling us to ascertain whether the glazing is pre or post 2002. For Scotland this data was not available, therefore the data for double glazing was taken from the SHCS but the proportion of double glazing that is Pre 2002 vs. Post 2002 was applied from the EHS.

Data for installations of glazing since April 2008 was taken from the CERT and CESP scheme reporting to Ofgem. This reporting is presented in terms of m^2 glazing provided. An average glazed area of homes in GB was used to divide the square meter data provided by Ofgem. It was assumed that the glazing was applied to whole dwellings rather than individual window replacements across a number of dwellings. The results of the glazing analysis are provided below:

Glazing		Potential	Stock (%)
Double glazing	Homes with post 2002 Double Glazing	8,685,169	31%
	Homes with Pre 2002 Double Glazing	17,277,138	62%
Single Glazing	Single Glazing	1,927,693	7%

5.1.5 Energy efficient doors

The English, Scottish and Welsh Housing Surveys 2008 each record the material construction of each external door as either UPVC, metal or wood. The predominant external door type for each property was taken to be representative of each of the property's external doors. It has been assumed each property with predominantly wooden or metal doors external doors will be suitable for replacement with an insulated door.

5.1.6 Draught proofing

In the absence of UK wide draught proofing potential data from any of the UK housing stock surveys, it is assumed that only dwellings that have primarily single glazing will substantially benefit from draught proofing strips. Double glazed dwellings would already have sealed window units not requiring further draught proofing. Although draught strips are applicable to external doors we deemed glazing to have a larger air leakage perimeter therefore have a larger influence upon the air leakage rate.

Draught Proofing	Potential	Stock (%)
Potential for Draught proofing (draught stripping)	1,903,707	7%
No potential for draught stripping	25,986,293	93%
Total	27,890,000	100%

5.1.7 Reduced infiltration

Reduced infiltration refers to the practice of sealing gaps, cracks and drafts in floor boards, lofts spaces, walls, windows and doors to minimise the air infiltration rate.

In calculating the potential for reduced infiltration, we used a recommended good practice level of air tightness of $7m^3/h/m^2$[5].

We then apportioned the housing stock in to three broad age categories, based on the Building Regulations requirements for air tightness in new build dwellings:

- Dwellings built before 2002
- Dwellings built between 2002 and 2008
- Dwellings built between 2008 and 2013

These age bands assume that the Building Regulations have impact in the real world approximately 2 years after publication.

EST sourced data on the number of dwellings that do not meet an air infiltration rate of $7m^3/h/m^2$ from the following sources:

- For dwellings built between pre 2002[6].
- For dwelling built between 2002 and 2008 and Post 2008[7]

A UK summary of the reduced infiltration analysis is provided below:

Reduced Infiltration	Potential	Stock (%)
Potential for Reduced infiltration (foam, strips, sealant use)	23,663,991	85%
No potential for reduced infiltration	4,226,009	15%
Total	27,890,000	100%

5.1.8 Boiler type

Data on condensing and non-condensing boilers is available from EHS, SHCS and LiW 2008. Condensing boiler installation numbers from 2008 – 2010 were sourced from HHIC. HHIC also provide projections of condensing boiler installations up to 2015. Both of these figures suggest condensing boiler installation number of 1 million per annum from 2008 – 2013 and therefore this figure was applied across the stock.

A UK summary of the boiler type analysis is provided below:

[5] EST (2005) *Improving Airtightness in Dwellings.* Good Practice Guide 224 (GPG 224). London, Energy Saving Trust.

[6] STEPHEN, R. K. (2000) *Airtightness in UK Dwellings.* BRE Information Paper IP 1/00. Garston, Watford, Building Research Establishment.

[7] GRIGG, P. (2004) Assessment of Energy Efficiency Impact of Building Regulation Compliance. A Report Prepared for the Energy Savings Trust/Energy Efficiency Partnership for Homes. Client Report Number 219683, Garston, Watford, Building Research Establishment.

Boiler type	Potential	Stock (%)
Condensing Boiler	10,236,838	37%
No boiler	3,508,407	13%
Standard Boiler	14,144,755	51%
Total	27,890,000	100%

5.1.9 Heating controls

The presence of the following types of heating controls was sourced from the English, Scottish and Welsh Housing Surveys:

- Thermostat
- Timer
- TRVs

EST calculated the combinations of all of these technologies in the stock, as well as the proportion where heating controls were not applicable (e.g. electric heating).

The 840,000 new build dwellings (2008 – 2013) were assumed to be built with a full package of heating controls (Thermostat, Timer and TRV) in the proportion of the stock where gas heating was assumed to be installed.

All new boiler installations were assumed to be installed with a full package of heating as this is specified in the Domestic Heating Compliance Guide 2008[8].

Data was available on the number of heating control installations under CERT. However, for this analysis it was assumed that none of these installations were additional to those accompanying new boilers.

A UK summary of the results for the heating controls analysis is presented below:

Heating controls	Potential	Stock (%)
Homes with No heating controls	660,017	2%
Homes with Room Thermostat only	135,564	0%
Homes with Timer only	973,708	3%
Homes with TRVs only	5,948	0%
Homes with Thermostat + timer	5,372,517	19%
Homes with Thermostat + TRVs	75,731	0%
Homes with Timer + TRVs	2,435,435	9%
Homes with Thermostat + Timer + TRVs	15,811,263	57%
Heating Controls not applicable (e.g. electric heating)	2,419,817	9%
Total	27,890,000	100%

[8] http://www.planningportal.gov.uk/uploads/br/BR_PDF_PTL_DOMHEAT.pdf

5.1.10 Hot water cylinder thermostat

Data on the presence of a hot water cylinder thermostat was sourced from the English, Scottish and Welsh housing surveys. New build dwellings were assumed to have a hot water cylinder thermostat. A UK summary of this analysis is provided below;

Hot Water Cylinder Thermostat	Potential	Stock (%)
Potential for Hot Water Cylinder Thermostat	4,611,718	17%
No potential for Hot Water Cylinder Thermostat	23,278,282	83%
Total	27,890,000	100%

5.1.11 Hot water cylinder insulation

The thickness of hot water cylinder insulation was taken the English, Scottish and Welsh housing surveys. The potential for hot water cylinder insulation included all homes with cylinders that had foam insulation under 26mm in thickness or a hot water cylinder jacket insulation less than 80mm in thickness. This is in accordance with recommendations in Appendix T of SAP 2009[9]. Homes without a hot water cylinder, for instance those with combi-boilers are classed as not applicable. Hot water cylinder insulation installations since April 2008 were sourced from Ofgem under the CERT programme.

A UK summary of the hot water cylinder insulation potential analysis are provided below:

Hot Water Cylinder Insulation	Potential	Stock (%)
Cylinder virgin insulation potential	27,787	0%
Cylinder top up insulation potential	5,004,822	18%
Not applicable	11,153,732	40%
No potential	11,703,658	42%
Total	27,890,000	100%

5.1.12 Energy efficient lighting

The Market Transformation Programme (MTP) Policy Scenario was used as an estimate of the number of light bulbs currently owned by UK households, grouped across various technology categories (e.g. GLS, CFL, Halogen, Linear Fluorescent, and LED). The scenario is a projection of the market under a defined set of relevant policies, extrapolated from 2007 Tangible / Lighting Association research[10]. It is used as the source for the number of light bulbs owned by UK households published in the DECC statistical release Energy Consumption in the UK (ECUK). The table below provides a summary of the assumed proportion of bulbs in each technology in an average UK home:

[9] DECC, (2011) The Government's Standard Assessment Procedure for Energy Rating of Dwellings

[10] The MTP Policy projection for 2013 has been used due to a lack of availability of any more recent robust audits of lighting. Some new market research sources are available but not at a reasonable cost and, based on analysis of other sources, it is not expected that new market research data would alter the potentials in any significant way.

Light Bulbs	Potential	Stock (%)
Standard (GLS) lamps	34,378,000	5%
Halogen lamps	294,985,000	41%
Linear fluorescent lamps	14,152,000	2%
CFL lamps	375,401,000	52%
LED lamps	4,643,000	1%
Total	723,559,000	100%

5.1.13 Passive Flue Gas Heat Recovery (PFGHR)

Passive flue gas heat recovery systems can be installed on all gas central heating systems. It was assumed that a statistically insignificant number already have the technology installed therefore all properties identified as having a gas heating have been classified as suitable for PFGHR. The system is recommended for condensing boilers only, therefore we have differentiated between homes that require just a PFGHR system and those that require a new boiler plus a PFGHR system.

Passive Flue Gas Heat Recovery	Potential	Stock (%)
Potential for passive flue gas heat recovery (would need to install an A-rated boiler and PFGHR)	432,409	2%
Potential for passive flue gas heat recovery (Upgrade to an A-rated boiler and Install a PFGHR)	12,710,522	46%
Potential for passive flue gas heat recovery (Install PFGHR)	9,626,211	32%
No potential for passive flue gas heat recovery	5,120,857	18%
Total	27,890,000	100%

5.1.14 Turning heating down by 1°C

According to the EST 2011 attitude and behaviour survey, 60% of households claim already to have their thermostat turned down, leaving 40% of households with the potential to reduce their internal temperature. Please note that as this is based on a single survey there is a large level of uncertainty associated with this figure and also, as a 'self-reported' survey, responses are likely to be subject to a significant 'green glow' bias towards answers that make the interviewee sound favourable in light of the nature of the questions. Nevertheless this was deemed to be the only data source available. All homes in the EHS, LiW and SHCS identified as failing health and safety due to cold risk were excluded from the potential leaving an overall potential of 32%.

Turning heating down by 1 degree	Potential	Stock (%)
Potential for 1 deg. C decrease in house temperature	8,790,724	32%
Already turns thermostat down by 1 deg. C	16,741,441	60%
Fails Thermal Comfort Standard - not suitable for turning down thermostat	2,357,835	8%

Total	27,890,000	100%

5.1.15 Turning off lights when not in use

The EST 2011 Attitude and Behaviour research project[11] found that 65% of household claim to always turn their lights off when out of the room. It has therefore been assumed that 35% of households could save energy by switching off unused lights.

Turning lights off when not in use	Potential	Stock (%)
Potential for turning off lights when not in use	9,761,500	35%
Already turn off lights when not in use	18,128,500	65%
Total	27,890,000	100%

5.1.16 Smart meters

DECC aims for all homes and small businesses to have smart meters by 2020. Between now and 2020 energy suppliers will be responsible for replacing over 53 million gas and electricity meters. This will involve visits to 30 million homes and small businesses[12].

Under the smart meter roll-out all homes will be offered a smart meter and, if they use mains gas, a smart gas meter. Alongside the smart meter, households will be offered an in-home-display, which can give near real-time information on gas and electricity use. The in-home-display (IHD) enables householders to make changes to their energy use.

The potential for domestic smart meters as at 2013 was calculated as follows:

For gas smart meters:

- All UK homes which currently use mains gas for heating

For electricity smart meters:

- All UK homes, minus an estimate of those who already have a smart meter, a smart-type meter, or an in-home-display. Although in-home displays do not provide all the benefits of a smart meter it was assumed that the behavioural changes resulting from installing a smart meter could be double counted if existing in-home displays were not taken in to account.

We estimated the number of homes which already have an IHD as part of an energy monitor or real time display from DECC's Quantitative research into public awareness, attitudes and experience of smart meters, giving an estimate of around 2.4 million IHD's in homes, which are used. This number was sense-checked against the number of real time displays given out under CERT and was found to be a good match (~3 million).

Smart meters – electric	Potential	Stock (%)
Potential for smart meters - electricity	24,866,019	89%
Already has a smart meter or electricity use monitor	3,023,981	11%

[11] EST (2011) Attitudes and Behaviour tracker survey (undertaken by SPA)
[12] https://www.gov.uk/government/policies/helping-households-to-cut-their-energy-bills/supporting-pages/smart-meters

Total	27,890,000	100%

Smart meters – gas	Potential	Stock (%)
Potential for smart meters - gas	22,769,143	82%
No potential for smart meter - gas	5,120,857	18%
Total	27,890,000	100%

5.1.17 Energy efficient appliances

Data about the stock ownership of domestic electrical appliances and the total energy consumed by these products across the UK was sourced from DECC's Energy Use In the UK (ECUK) 2012 tables 3.12, 3.11 and 3.10. The modelled data used to produce these tables came from the Market Transformation Program[13]. The appliance categories or sectors covered in the model are as follows:

Appliance type	Description
Cold appliances	Chest freezer
	Fridge freezer
	Refrigerator
	Upright freezer
Wet appliances	Washing machine
	Tumble driers
	Dishwasher
Cooking	Electric ovens
Consumer electronics	Primary TV
	Secondary TV

This data enabled us to calculate the average electricity consumption per appliance. For cold appliances, wet appliances and electric ovens the ECUK provides stock data of appliances by their energy rating. The EU energy label calculations were used to assess the average consumption for each appliance, where the stock of appliances by energy band was known, with the following assumptions alterations made:

Appliance	Assumption
Chest freezer	Average size 163 litres
Fridge freezer	Average size 253 litres, 2/3rds of volume is frost free fridge
Refrigerator	Average size 144 litres with frost free setting*
Upright freezer	Average size 123 litres

[13] Briefing notes on how each of these product category stock models were calculated are available here: http://efficient-products.ghkint.eu/product-strategies/viewall/briefing-note.html#viewlist

Washing machine	Average size 6kg, 220 washer per year 150 at 40 degrees C, 66 at 60 degrees C and 5 at 90 degrees C
Tumble dryer	Average size 6kg, 260 cycles per year
Dishwasher	245 washes per year, 110 at 65 degrees C
Electric ovens	Consumption based on MTP WhatIf data
Televisions (Primary)	Average size 36” Average on time 1,742 hours, and 4,211 hours on standby per year
Televisions (Secondary)	Average size 21” Average on time 1,742 hours, and 4,211 hours on standby per year

Average product size assumptions are derived from GfK sales data. GfK sales data from 2008 to 2012 was used to modify the overall stock of cold and wet appliances, electric ovens and televisions. ICT products (PC's, laptops and tablets) have not been considered due to insufficient data on the variation in energy rating and historical evidence of the shift form PC and laptops to tablets. In 2010 the EU energy labelling legislation for televisions was passed. GfK data on the sales of televisions by energy label from 2012 was used to estimate the stock of televisions by energy band.

All data above was used to calculate the average consumption per appliance, the number of each appliance in stock and the average consumption per appliance per energy rating, where appliances had energy labels. For each appliance category where EU energy labels apply, a certain proportion of the stock purchased before the introduction of labelling were not categorised under the A+++ to G rating. For these uncategorised appliances (labelled as “other”) their average annual consumption is equal to the total consumption of all appliances in the sector minus the consumption of the appliances with a known energy label, divided by the number of uncategorised appliances.

5.2 Total stock savings

The technical potential for each measure is used to determine the potential for energy and CO_2 emission savings across the whole UK stock. The potential across the 135 individual house types are combined with the energy savings identified for the house type to get the contribution to total stock savings from that measure. The resulting energy and CO_2 savings across the whole UK stock is shown below:

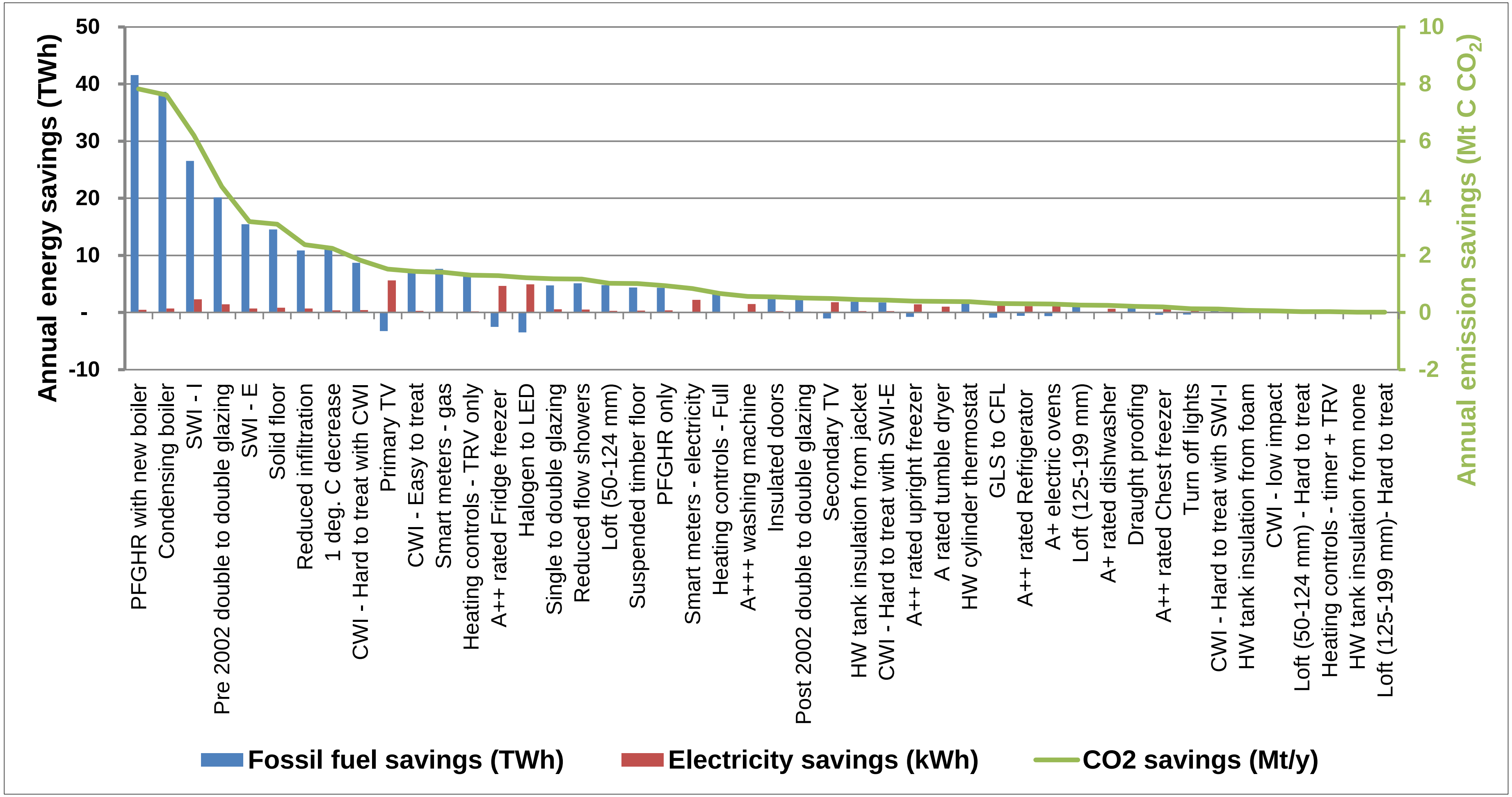


Figure 10 Total potential for annual energy savings across stock

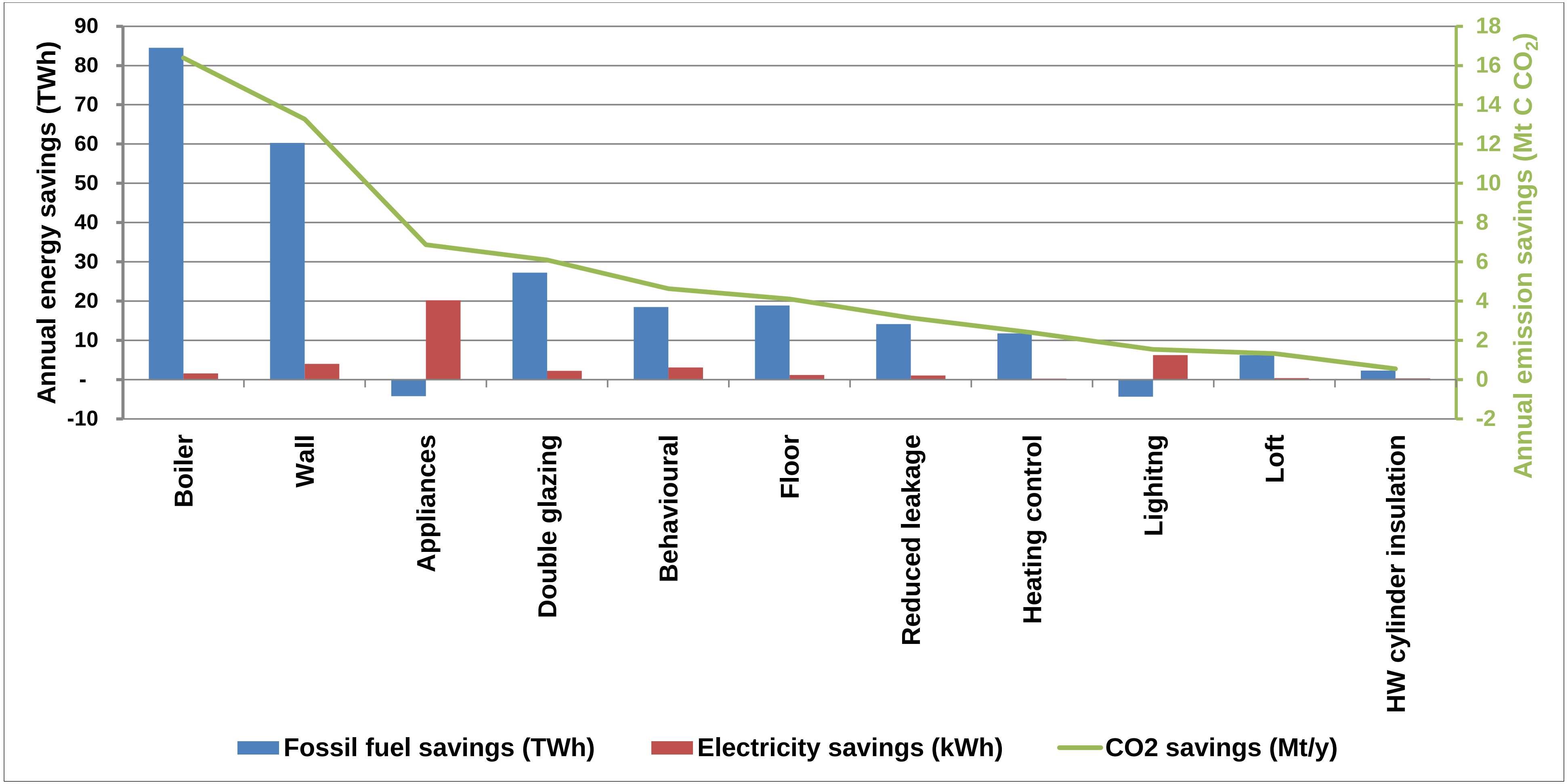


Figure 11 Total potential for annual energy savings across stock

The biggest potential for energy savings is from boiler replacement, SWI, heating controls with TRV and pre 2002 double glazing, while appliance replacement with A++/A+++ energy rating also has good potential for CO_2 emission reduction.

5.3 Overlapping savings between measures

The measures include some level of overlapped savings e.g. the majority of the saving from passive flue gas heat recovery (PFGHR) with a new boiler comes from the installation of the condensing boiler rather than the PFGHR itself. Also, with the reduction of baseline heating demand through installation of thermal measures, the potential savings from boiler replacement reduces. Taking this double counting of savings into account, the revised potential for CO_2 emission reduction is **49Mt/y**. The breakdown of this total potential by measure is shown in the figure below. It should be noted that these savings do not take into account uptake of low carbon heating technologies such as heat pumps (HP) and combined heat and power (CHP) systems, i.e. these savings are not additional to the emission reduction from a shift of heating technology towards low carbon heating technologies. With a significant uptake of low carbon heating solutions, the potential for additional savings from energy efficiency measures is further reduced.

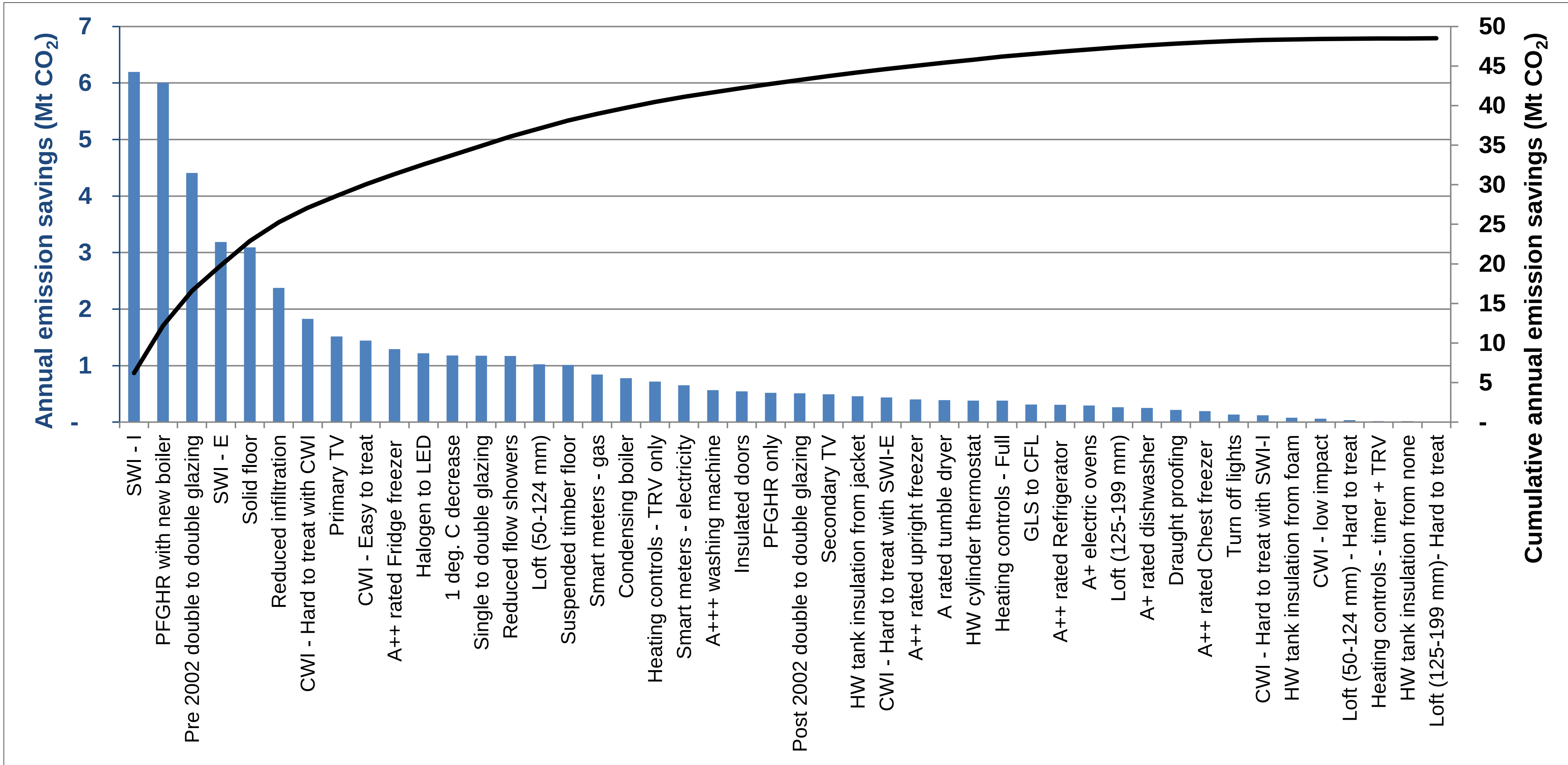


Figure 12 Total potential for annual emission savings across stock with double counting removed

6 In use factors

6.1 Overview

There is growing evidence that there is often a gap between the actual in-situ performance and the theoretical performance we can expect from energy efficiency measures. This is of substantial interest in this study as it directly challenges the confidence with which we can estimate the energy, cost and carbon savings resulting from the measures analysed. A number of factors have been posited as contributing to this observed discrepancy. These include:

- Variation in thermal performance of building fabrics and in particular the effect of using standardized U-value assumptions.
- Underperformance of measures in-situ when compared to laboratory expectations, including deterioration of performance over time.
- Imperfect installation and inaccessible/untreatable areas.
- Changes in occupant behaviour in response to installation that cannot be well described or predicted by conventional models; including internal temperature (thermal comfort behaviour), ventilation ("heat dumping"), and user-control (how effectively they use thermostat, timer etc.).
- Models have difficulty explicitly describing heat demand accounting for secondary sources (often unmetered), and hot water and appliance use (as separable from space heating).

6.2 Methodology

The requirement for the purposes of this study is to identify from current research the best available estimates that we can use to adjust expected savings.

Our approach was first to take the DECC Green Deal in-use factors[14], and inaccessibility and comfort factors from the DECC Green Deal Impact Assessment[15], and then to critically evaluate the sources and justification for these, including against any new or overlooked evidence and insight from our field trial experience. DECC in use factors were used as the basis of the study as this is the only place where in-use factors have been systematically developed across all measures.

A particular focus has been on assessing how conservative the DECC factors may be as, whilst conservatism is pertinent from a Green Deal delivery perspective, it is not appropriate for the MACC and trajectory analysis. However, it should be noted that DECC employ the same in-use factors in their Green Deal Impact Assessment as they do in household Green Deal calculations, with the addition of comfort and inaccessibility elements.

[14] DECC (2012): How the Green Deal will reflect the in-situ performance of energy efficiency measures.
[15] DECC (2012): Final stage impact assessment for the Green Deal and Energy Company Obligation.

The DECC Green Deal In-use factors, In line with previous research (Sanders and Phillipson, 2006)[16], are partitioned into three theoretically, and in some evidence empirically, separable elements that contribute to an overall reduction factor:

1. In-use factor
2. Comfort factor
3. Inaccessibility factor

The in-use factor is the physical underperformance or systematic difference between physics-based models of building energy demand and real-life. The comfort factor, or comfort take, is the underperformance of a refurbishment measure attributable to the rebound effect observed whereby internal temperatures increase following an improvement in insulation. The inaccessibility factor describes, broadly, the proportion of the building stocks surface area which cannot be treated – primarily important for walls.

These are applied multiplicatively to modelled savings to provide a more accurate estimate, as in the formula below:

$$\Delta kWh_A = \Delta kWh_M \times [(1 - In\ use) \times (1 - Inaccessibility) \times (1 - Comfort)]$$

Figure 13 Calculation of savings after in use factors are applied

6.3 Measure in use factor breakdown

The table below presents the proposed reduction factors for use within this study. We have adopted the three classifications used by DECC. This has the benefit that we can apply these separately to savings estimates should we feel any of them inapplicable. The evidence supporting these and discussion of their suitability can be found in the appendix.

[16] Sanders & Phillipson (2006): An analysis of the difference between measured and predicted energy savings when houses are insulated. Glasgow Caledonian University.

Table 6 Detailed breakdown of performance factors for measure

Measure	In – use	Comfort factor	Inaccessibility	Total IUF
SWI – Internal / external	33%	15%	10%	49%
CWI	35%	15%	10%	50%
Loft	35%	15%	10%	50%
Suspended timber floor	15%	15%	0%	28%
Solid floor	15%	15%	0%	28%
Double glazing	15%	15%	0%	28%
Insulated doors	15%	15%	0%	28%
Draught proofing	15%	15%	0%	25%
Reduced infiltration	15%	15%	0%	25%
Condensing boiler	25%	0%	0%	25%
Heating controls - Full	50%	0%	0%	50%
HW cylinder thermostat	10%	0%	0%	10%
HW tank insulation	15%	0%	0%	15%
GLS to CFL	0%	0%	0%	0%
Halogen to LED	0%	0%	0%	0%
PFGHR only	0%	0%	0%	0%
1^{o}C decrease in temperature	10%	0%	0%	10%
Turn off lights	0%	0%	0%	0%
Smart meters - electricity	0%	0%	0%	0%
Smart meters - gas	0%	0%	0%	0%

6.3.1 Discussion of Evidence

Whilst underperformance of energy efficiency measures, particularly insulation, against theoretical expectations has been routinely observed in post-occupancy evaluations and field trials, this insight has not often been structured and collected in such a way that it can be used directly to derive quantified adjustment factors. Limitations around data collection methodology, sample size, and representativeness, create problems for the identification of generalized factors – and there has been relatively little dedicated effort to develop empirical reduction factors as a primary research output. Acknowledging this, we present here a review of available secondary evidence and a comment on its applicability and robustness for our purposes.

The key focus of the discussion is on DECC's Green Deal In-Use and Impact Assessment numbers. They have justified these where possible with cited evidence, and our review of this confirms that their use of these sources is appropriate and is a comprehensive representation of currently available research.

6.3.2 Cavity Wall Insulation

The majority of studies that have sought to quantify reduction factors have focused on the most widely installed insulation measures (cavity wall and loft). Sanders and Phillipson (2006) provide a useful review of reduction and comfort factor estimates for cavity and loft insulation. This compares findings from studies that provide quantified values, and identifies central factors that are in agreement with these – proposing a reduction factor of 50% (based on 4 studies), of which comfort taking contributes around 15% (based on 3 studies). Whilst it does highlight the limited availability of evidence, this is nonetheless the most comprehensive contribution and provides the primary basis for DECC's proposal of 50%. Early evidence from recent analysis of the National Energy Efficiency Data-framework (NEED) corroborates this, finding around a 50% underperformance of CWI in reality[17]. Field trials of refurbishments have approximated that around 10% of wall coverage remained unfilled following the treatment (AEA, 2004)[18]. There is a range of supporting evidence of underperformance of measures in situ, proposing a range of causes.

Given the available evidence, and in line with DECC proposals, a reduction factor of 50% is reasonable, and there is not sufficient evidence to suggest that this is overly conservative. This is our suggested reduction factor.

6.3.3 Solid Wall Insulation

Due to the relatively low numbers of refurbishments for evaluation, there is much less evidence on reduction factors for solid wall insulation. Based on recommendation DECC initially proposed an in-use factor of 25%. Following evidence from field trials, an additional 8% adjustment (to 33%) was made for pre-1966 brick properties which were found to have higher than assumed pre-insulation U values. EST has undertaken a two phase field trial of Solid Wall insulation. Analysis of the first phase, with a sample of nearly 100 properties, found that un-insulated solid wall U values were on average 32% lower than otherwise assumed by SAP (2.1 $W/m^2.K$)[19]. The trial contained both brick and stone properties, and very few solid wall constructions will have been built since 1966. As a result we propose that the +8% adjustment is extended to all types of solid wall property.

Analysis of the second phase, with a smaller sample of around 35, is ongoing. However early results have found a discrepancy between actual and modelled savings of a similar order of magnitude of DECCs proposed factors – suggesting that these are reasonable. Whilst in-use, comfort and inaccessibility cannot be independently identified in the field trial results, and the sample is too small to generalise about individual heating behaviour or installations, it seems reasonable to suppose that all wall insulation has a similar effect on occupant heating behaviour. There will also be untreated areas of wall, for example stone detailing, inaccessible/awkward areas; as clear in thermal imaging analysis. For consistency the proposed figure of 10% for inaccessibility is apposite.

[17] For example DECC (2012): Final stage impact assessment for the Green Deal and Energy Company Obligation

[18] Capel, C. & Wilczek, J. (2004): Measurement of the Performance of Cavity Wall Insulation Installed in Domestic Dwellings, Final Report for Energy Saving Trust, AEA Technology plc

[19] EST Field trials. Field trial results not published externally

Subsequently, in line with DECC, we suggest that 33% be used as the in-use factor, 15% as the comfort factor and 10% as the inaccessibility factor for all types of solid wall property. When compared against the initial results of the Energy Saving Trust's field trial, as well as the value for a similar measure in CWI, these do not appear overly conservative.

6.3.4 Loft Insulation

As with CWI, the key contribution comes from Sanders and Phillipson (2006) since the majority of the studies reviewed measure the reduction factor from installation of both CWI and loft insulation. Loft insulation therefore is expected to also produce a savings underperformance of 50% when compared to theoretical expectations. As with CWI, early NEED analysis has found a similar 50% reduction factor. These measures are often grouped together in such studies as they are an insulation package that has been typically installed in recent retrofit programmes. It has been suggested that measures that increase radiant temperature (e.g. CWI, double glazing) will generate a lower comfort take than those that do not, such as loft insulation. BRE (2003)[20] find that properties with CWI alone saw a significantly smaller comfort take (7%) than those with loft alone (29%). However EST (2008)[21] in attempting to differentiate the energy savings from CWI and loft insulation installed under EESoP3 and EEC, find that there was no significant difference in overall reduction factor between the two measures. BRE (2006)[22] in an ex-post study of the effectiveness of loft insulation find a few factors in installation that reduce its coverage, such as areas of space left for heat escape from ceiling lights. More substantially they highlight imperfections in installation – and this may be a particular issue given the popularity of DIY loft insulation installation. Due to the nature of the insulation, a lower inaccessibility factor seems reasonable whilst a higher in-use factor due to imperfect or degraded installation also seems reasonable. In the Green Deal Impact Assessment inaccessibility and in-use are grouped (as 41%), and whilst this is not explained in the document it does suggest some uncertainty around the appropriate split between these.

Considering the evidence then, we propose that loft insulation has the same overall reduction factor as cavity wall insulation. Contributing to this, we suggest that a slightly higher in-use factor (38%) and lower inaccessibility factor (5%) is used. This is to reflect evidence that the split of contributing factors may be different to wall insulation – specifically that issues in installation may be more likely due to poor or degraded installations than to spatial coverage. We are satisfied that the DECC factors are not overly conservative.

6.3.5 Other Insulation Measures

There is very little evidence for appropriate reduction factors for other insulation measures – floor, glazing, doors, draught proofing and reduced infiltration. DECC apply a 15% in-use factor to each of these based on expert recommendation, and in recognition that this is a precautionary value. When considered against the size of observed discrepancy evidenced for loft and cavity insulation, we do not deem this an excessive value – despite lacking the evidence to discuss with any precision its accuracy. Since these are also

[20] Building Research Establishment (2003): Standards of Performance 2: Findings from Monitoring. BRE Client Report 16099, Building Research Establishment, Watford

[21] Energy Monitoring Company (2008): Disaggregation of the energy savings achieved from insulation in EESoP3 and the Energy Efficiency Commitment. Final Report Updated November 2008 for Energy Saving Trust.

[22] Building Research Establishment (2006): Research into the effectiveness of loft insulation Phases II & III. BRE Client Reports 227479 and 227480, Building Research Establishment, Watford.

insulation measures that affect internal thermal comfort, we recommend that the standard comfort factor of 15% be applied; in line with Sanders and Phillipson's review.

6.3.6 Condensing Boilers

DECC have proposed an in-use factor of 25% applied to the saving when switching a non-condensing boiler to a condensing gas or oil boiler. This is in recognition of field trial evidence that condensing boilers underperform in situ compared to theoretical performance. The condensing boiler field trial undertaken by Gastec and the Energy Saving Trust for DECC (2009) finds that the mean heat efficiency of condensing boilers is significantly less than suggested by mean SEDBUK seasonal efficiencies – as used in SAP. The trial recommends a correction factor of ~0.95 to improve the correlation between trial efficiency and SAP predicted efficiency; however this may be lower during the summer months when domestic hot water is the primary function. However, the pure system efficiency alone does not account for all of the possible factors affecting performance in use, including, for example where SAP can potentially overestimate original energy use. For this reason, and through lack of available evidence, we recommend that the 25% factor assumed by DECC be applied. Of all the DECC in-use factors, this could be seen as being conservative but no other evidence exists to counter this assumption. It is unclear from the literature to what extent real-life performance data from NEED was available to inform DECC's assumption.

6.3.7 Heating Controls

The in-use factor proposed by DECC for heating controls is 50%. This is a slightly atypical use of the in-use approach as it is less to identify underperformance and more to question whether there is evidence for any saving from this measure. Shipworth et al (2010)[23] review the evidence for savings from heating controls and undertake a trial of 427 homes to test thermostat and timer controls. They find very little robust evidence for a saving, identifying poor and misleading sourcing as a particular issue in policy evaluations of this measure. In their trial, they do not find evidence for any energy saving impact of the measure. Specifically, homes with a thermostat installed did not have a significantly different average internal temperature and homes with a timer installed did not have a significantly different average daily heating duration. Nonetheless savings have been found in some studies, for example RLW Analytics (2007)[24] which found a 6.2% reduction in gas consumption from the installation of programmable thermostats. Comfort and inaccessibility factors are inapplicable here due to the nature of the measure.

Clearly further research is required around this measure to determine its likely savings, and the application of an in-use factor reflects this, rather than any specific limitations of models. DECC cite the Shipworth et al study as evidence that controls may underperform in reality against theoretical expectations and this seems reasonable. The choice of a 50% in-use factor however is less certain. If we were to expect no savings, then we would apply a 100% reduction factor and eliminate heating controls as an option. However, as insufficient evidence exists to substantiate this claim either way, the DECC assumption of 50% seems a more reasonable working assumption.

[23] Shipworth, M., Firth, S.K., Gentry, M.I3, Wright, A.J., Shipworth, D.T. and Lomas, K.J. (2010): Central heating thermostat settings and timing: building demographics, *Building Research & Information*, 38(1), 50-69.
[24] RLW Analytics (2007): Validating the impact of programmable thermostats. Middletown, CT, Prepared for GasNetworks by RLW Analytics.

7 Measure cost

7.1 Overview

EST undertook an analysis of available data on the cost of measures to derive estimated costs for all measures on the MACC. All measure costs are presented in terms of the price charged for the work by an installer and therefore include all the cost of materials, labour costs and VAT, plus any transaction costs associated with finding the lead and marketing etc. However, please note that in the policy analysis, there are certain additional costs associated with the ECO and Green Deal which were assumed to be additional to the standard costs of marketing and assessment. These additional costs refer to the Green Deal Advice Report and Technical Surveys required by ECO and Green Deal. It is also assumed that for certain elements of ECO, there are additional costs of finding qualifying leads due to the restricted eligibility criteria. These additional costs are covered separately below.

All the costs provided exclude the value of grants and subsidies and hidden or hassle costs. The analysis of measure costs has, where possible, tried to distinguish between fixed and marginal elements. The fixed value is independent of the capacity or size of the measure and may include, for example, in the case of external solid wall insulation the fixed cost of transport to the job site. Marginal costs, for instance in the case of wall insulation, include the cost of materials per m^2 of wall insulated.

Each of the property types within the Housing Energy Model falls under one of three categories of shape and dimension: Small (representing all flats), Medium (representing all bungalows and terraced homes) and Large (representing all detached and semi-detached homes). In order, to apply the variable costs to these archetypes, typical dimensions for each were established from the BRE's Standard Dwellings for Energy Modelling document[25].

[25] ILES. P, J (1999) Standard Dwellings For Energy Modelling, Centre for Technology Statistics and Assessment, Department of the Environment Transport and the Regions.

7.2 Measure cost breakdown

The results of the costs analysis is presented below.

Table 7 Detailed cost breakdown of measures

Measure	Fixed costs	Variable cost	Low Fixed Cost	Low Variable Cost	High Fixed Cost	High Variable Cost	Variable cost unit	Variable
External wall insulation	£6,000.00	£111.49	£3,600.00	£111.49	£8,400.00	£111.49	m2	Wall Area
Internal wall insulation	£2,400.00	£73.35	£1,200.00	£66.01	£3,600.00	£80.68	m2	Wall Area
Easy to treat cavities	£250.12	£5.06	£236.95	£4.04	£263.28	£5.15	m2	Wall Area
Hard to treat cavities (CWI Solution)	£2,240.42	£4.76	£1,293.31	£3.80	£2,875.70	£4.84	m2	Wall Area
Limited savings easy to treat cavities	£250.12	£5.06	£236.95	£4.04	£263.28	£5.15	m2	Wall Area
Loft Insulation	£157.97	£0.012	£144.805	£0.011	£171.134	£0.013	mm x m2	Thickness required * Loft Area
Hard to treat lofts	£986.82	£22.79	£564.06	£13.03	£1,763.46	£40.73	m2	Loft area
Solid floor insulation	£0.00	£29.27	£0.00	£24.85	£0.00	£46.22	m2	Ground Floor Area
Suspended timber floor insulation	£0.00	£8.81	£0.00	£2.18	£0.00	£13.26	m2	Ground Floor Area

B-rated double glazing	£1,683.62	£108.65	£1,482.16	£95.65	£1,885.07	£121.65	m2	Window Area
Insulated doors	£0.00	£504.47					per door	Number of doors
Draught proofing	£0.00	£3.57					m	Window and Door Perimeter
Reduced infiltration treatment	£22.01	£3.57					m	Window and Door Perimeter
Condensing boiler	£2,401.52	£0.00	£700.00		£5,998.31		per dwelling	Number of dwellings
Heating controls (Timer, Thermostat and TRV)	£451.71	£0.00					per dwelling	Number of dwellings
Heating controls (Timer and TRV)	£368.68	£0.00					per dwelling	Number of dwellings
Heating controls (TRVs only)	£168.84	£0.00					per dwelling	Number of dwellings
Hot Water Cylinder Thermostat	£119.99	£0.00					per Unit	Number of dwellings
Hot Water Tank insulation	£12.65	£0.00					per Unit	Number of dwellings
Halogen lamps	£0.00	£2.89					per Bulb	Number of bulbs replaceable
CFL lamps	£0.00	£5.52					per Bulb	Number of bulbs replaceable

LED lamps	£0.00	£9.80					per Bulb	Number of bulbs replaceable
Passive Flue Gas Heat Recovery	£652.79	£0.00					Number of dwellings	Number of dwellings
Smart meter (gas and electric)	£212.28	£0.00					per meter	Number of meters
Chest freezer	£270	£0.00					per unit	per unit
Fridge freezer	£278	£0.00					per unit	per unit
Refrigerator	£276	£0.00					per unit	per unit
Upright freezer	£442	£0.00					per unit	per unit
Washing machine	£321	£0.00					per unit	per unit
Tumble driers	£236	£0.00					per unit	per unit
Dishwasher	£365	£0.00					per unit	per unit
Electric ovens	£382	£0.00					per unit	per unit
TV	£542	£0.00					per unit	per unit

The following methodology statement provides details of how costs data was sourced and analysed for imputation in the MACC model.

7.2.1 Solid wall insulation, Internal and External

Costs for solid wall insulation were taken from the Solid Wall Insulation Supply Chain Review (2009)[26] undertaken by Purple research on behalf of the Energy Saving Trust and the Energy Efficiency Partnership for Homes. The fixed costs for both types of wall insulation were taken from the report. To calculate the variable costs the average material costs as given in the report were divided by the typical wall area for a large semi-detached home (81.9 m^2) as given in BRE's Standard Dwellings for Energy Modelling document[27]. Costs quoted in the report were exclusive of VAT hence 20% was added to both the fixed and variable costs. To calculate the low and high estimated costs, the ranges provided in the underlying Purple Research report were used. The Purple Market Research was deemed to be a more robust dataset than industry data from schemes such as CESP as it is often difficult to establish the true un-subsidised cost under energy efficiency obligation programmes.

7.2.2 Cavity wall insulation (Easy to treat)

It is difficult to establish the unsubsidised cost of cavity wall insulation due to the fact that the market has been almost entirely subsidised since the Energy Efficiency Commitment was established in 2002. The National Insulation Association (NIA) recently carried out a survey of its members[28] and established that the current average price for insulating a 3 bedroom semi-detached home without subsidy is £450 - £500. The high and low cost estimates were based on this range.

7.2.3 Cavity wall insulation (Hard to treat)

There are several forms of hard to treat cavity under DECC's definition. The appropriate solution varies depending on the type of cavity wall and the particular circumstances of the property meaning that costs can vary greatly between the different hard to treat types. To establish the solution most suitable to each hard to treat type, EST referenced the report commissioned by DECC on Hard to Treat Cavity Walls, first in 2010[29] and subsequent revisions in 2012[30] which provides recommendations for different uses. In a number of cases (e.g. Narrow cavity walls) there is no clear guidance as to the appropriate solution. Therefore, an assumption was made based on the EST Housing Teams Technical Knowledge.

Costs for these treatments were sourced from the Inbuilt 2010 and 2012 reports for DECC on hard to treat cavities, the EST supply chain research for solid wall insulation, Spon's Architects and Builders Price Book 2013[31] and a report from Calderdale Council[32] containing case studies on the costs of insulating different types of hard to treat cavity wall.

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[26] Purple Market Research (2009) Solid Wall Insulation Supply Chain Review, Energy Saving Trust, Energy Efficiency Partnership for Homes.

[27] ILES. P, J (1999) Standard Dwellings For Energy Modelling, Centre for Technology Statistics and Assessment, Department of the Environment Transport and the Regions.

[28] National Insulation Association (http://www.nia-uk.org/)

[29] http://www.bre.co.uk/filelibrary/pdf/rpts/Hard_to_Treat_Homes_Part_I.pdf https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65993/788-hard-to-fill-cavity-walls-domestic.pdf

[30] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48433/5620-review-of-the-number-of-cavity-walls-in-great-brit.pdf

[31] SPON'S Architects' and builders' price book 2013 ISBN:978-0-415-69077-5

High and low cost estimates were sourced from the Inbuilt report where available.

It was assumed that Limited potential cavity walls cost the same to treat as conventional cavity walls as the technical requirements are identical to standard cavity wall insulation.

To ascertain an average fixed and variable cost, a weighted average cost of treatment was calculated according to the population distribution of hard to treat cavities. Detailed below are the types of hard to treat walls, the assumed solution and the proportion of walls that meet this criterion.

Type of hard to treat cavity wall	Treatment	Proportion of hard to treat walls
Narrow cavity	Assumed that standard cavity wall insulation is applied	17%
Concrete frame	Standard cavity wall insulation installed after remedial work carried out on concrete skin. The cost of wall fault remedial work is based on the average cost of cleaning cavities, installing a new damp proof course and repairing external render as sourced from the Inbuilt 2010 report (weighted according to the proportion of wall faults of each type in the EHS 2008)..	10%
Random stone	Internal solid wall insulation (ISWI) is assumed to be the preferred solution because the uneven internal cavity surface would mean that conventional cavity wall insulation (CWI) may not fill and spread evenly. It is assumed the outside facade is preferred not to be insulated for aesthetic reasons.	4%
Metal Construction	ESWI assumed to be the preferred solution due to potential moisture penetration and damage to the metal frame if installing standard cavity wall insulation.	1%
Timber Frame	ESWI assumed to be the preferred solution. Due to potential vapour diffusion issues if using standard cavity wall insulation is it recommended to use ESWI in timber frame properties	3%
Wall Fault	Assumed that conventional cavity wall insulation is applied once wall fault is treated. The cost of wall fault remedial work is based on the average cost of cleaning cavities, installing a new damp proof course and repairing external render as sourced from the Inbuilt 2010 report (weighted according to the proportion of wall faults of each type in the EHS	51%

[32] Calderdale Council (2011) Hard to Treat or Hard to Fund? Final Report Retrofit Insulation Pilot Project, Calderdale Council.

	2008).	
Too high (e.g. tower blocks)	Costs provided in InBuilt 2012 report for this treatment	5%
Exposed location (i.e. those in coastal locations or frequently exposed to driving rain)	Water proof external wall insulation used to prevent moisture penetrating into the inner wall	9%

When applying these costs to the MACC and trajectories, three costs were used depending on the recommended solution

- Internal wall insulation cost
- External wall insulation
- An average of the hard to treat cavity wall cost

Hard to treat cavity type	Fixed cost	Variable cost
Narrow cavity	£250.12	£5.06
Concrete frame	£6,000.00	£111.49
Random stone	£2,400.00	£73.35
Metal construction	£6,000.00	£111.49
Timber has cavity	£6,000.00	£111.49
Wall fault	£3,083.45	£5.06
Too high	£4,000.00	£0.00
Exposed location	£250.12	£5.06

7.2.4 Loft Insulation

According to a survey of NIA members[33] the unsubsidised cost for insulating a 3 bed semi-detached home is £300. As loft insulation is generally made of fibreglass, a relatively inexpensive material, it has been assumed that 53% of the costs insulating a 3 bedroom semi-detached home are fixed and 47% are variable, as per assumptions previously used in the housing energy model. 47% of the variable cost was divided by the roof area of a large semi-detached home (44.4 m^2) according to the BRE Standard Dwelling dimensions. The NIA did not provide a range of cost estimates for loft insulation, however, it was assumed that the same costs range would apply as was provided for cavity wall insulation. Therefore, a cost range of £275 - £325 was assumed for loft insulation. To calculate the high and low range for hard to treat loft insulation, the average, min and max costs data was sourced from the Calderdale Council report. The % range against the average was used as the high and low range.

[33] National Insulation Association (http://www.nia-uk.org/)

7.2.5 Floor Insulation (for Solid and Suspended Timber Floors)

Data on the costs of floor insulation was unavailable from the NIA. The best available source was deemed to be from the EST Pay As You Save (PAYS) pilot scheme which has records for the cost of floor insulation in 13 properties that had their floors insulated alongside a description of each properties built form. There are two forms of floor insulation: solid floor insulation and suspended timber floor insulation, the latter being generally more expensive than the former. The cost of installation in the PAYS pilot varied significantly from £160 to £1,820. The PAYS pilot data did not record what type of floor was insulated however based on property age and a natural grouping of costs in to two broad groups it was assumed that all installations costing less than £900 were suspended timber floor and those costing over £900 were solid floor insulation. The total installation costs were divided by the assumed ground floor area for each property type, as per the BRE Standard Dwelling dimensions to calculate the variable cost per square meter. No fixed installation cost was calculated. It should be noted that the incredibly small sample size of this dataset means that the figures derived should be treated with caution and further research is necessary to establish a reliable average cost for different types of floor insulation. To calculate the high and low cost estimates the range of costs provided in the PAYS data was used.

7.2.6 Double glazing

Data from the Glazing Federation for the cost of fitting C rated double glazing to 7 properties, along with the total window area replaced was processed using a regression analysis to calculate the fixed and variable costs for installation. Then using Spon's[34] glazing cost estimation for installing A and C rated glazing we split out the total cost into a fixed and variable format using the ratio between the two from the Glazing Federation data. New VAT rates were applied to the costs. Data collected by Which showed A rated triple glazing to be 1.8 times more expensive than C rated glazing[35]. For this analysis, it was assumed that the costs of B rated glazing would be half way in between the costs and A and C rated glazing.

7.2.7 Insulated Doors

Average costs were derived from online research into insulated door costs from a sample of 41 quotes. All doors with a U-value of 1.2 or lower are classed as insulated doors, although insulated doors can be found with U-values as low as 0.6. Spon's Architects and Builders Price Book 2013[36] was used to determine the installation cost. It is assumed to take 1.5 hours to install a door at a cost of £46.13 per hour for labour.

7.2.8 Draught Proofing

The NIA quote that the unsubsidised cost for draught-proofing a 3 bedroom semi-detached home is £200. The total perimeter of all windows and doors in a 3 bedroom semi-detached home were taken from BRE's standard dwellings (5.61 meters). This was used to calculate the variable installation and material cost per meter of material required.

[34] SPON'S Architects' and builders' price book 2013 ISBN:978-0-415-69077-5
[35] http://www.which.co.uk/home-and-garden/home-improvements/reviews-ns/best-double-glazing-companies/double-glazing-prices/
[36] SPON'S Architects' and builders' price book 2013 ISBN:978-0-415-69077-5

7.2.9 Reduced Infiltration

The cost of reduced infiltration is assumed to be the same as draught proofing with the inclusion of a fixed cost for expanding foam and decorators sealant used for blocking gaps. The costs for these extra materials were sourced from online searches of three major online DIY retailers.

7.2.10 Boiler Upgrade

Installation cost data for new condensing boilers was sourced from the 2010 boiler scrappage scheme. Several thousand quoted unsubsidised prices were analysed to obtain the average cost for installing an A rated boiler in each of the three categories of house sizes used in the Housing Energy Model for both oil and gas boilers. The installation costs assume that the household previously had a wet central heating system.

7.2.11 Heating Controls (Central Heating Programmer, Room Thermostat and Thermostatic Radiator Valves (TRVs))

Material costs for heating controls were sourced from online research of 3 major DIY retailers[37]. The installation costs were taken from the Spon's Electrical and Mechanical Price Book 2013. The installation time of 1.15 hours was assumed charged at the same hourly rate as a boiler installation.

7.2.12 Hot Water Cylinder Thermostat

Material costs were sourced from online research of 3 major DIY retailers[38]. The installation costs were taken from the Spon's Electrical and Mechanical Price Book 2013. The installation time of 30 minutes was assumed to be charged at the same hourly rate as a boiler installation.

7.2.13 Passive Flue Gas Heat Recovery (PFGHR)

The most popular PFGHR unit on the market currently costs £550[39]. Installation costs were assumed to be £103 as per Spon's 2013 Mechanical & Electrical Price Book for 30 minutes work. Please note that the PFGHR refers to only the cost to install and buy the unit, it does not including the cost of a gas condensing boiler if required.

7.2.14 Smart Meters

Costs per unit were derived from the DECC impact assessment on smart meters[40], dividing the total business costs of £12.1 billion by the number of meters to be installed. This is assumed to be installed is 57 million according to Consumer Focus Report Go Smart, Get Smart[41].

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[37] Wicks, B&Q and Screwfix.

[38] Wicks, B&Q and Screwfix.

[39] Bourgeois. P, (2012) Mechical Ventilation and Heat Recovery Postive Input Ventilation and GasSaver Units Supply Chain Installer Analysis, Zero Carbon Britain, Energy Saving Trust.

[40] DECC (2013) *Smart meter roll-out for the domestic and small and medium non-domestic sectors*. IA No: DECC0009

[41] Consumer focus (2013) Go smart, get smart: http://www.consumerfocus.org.uk/files/2012/05/FAQ-Go-smart-get-smart5.pdf

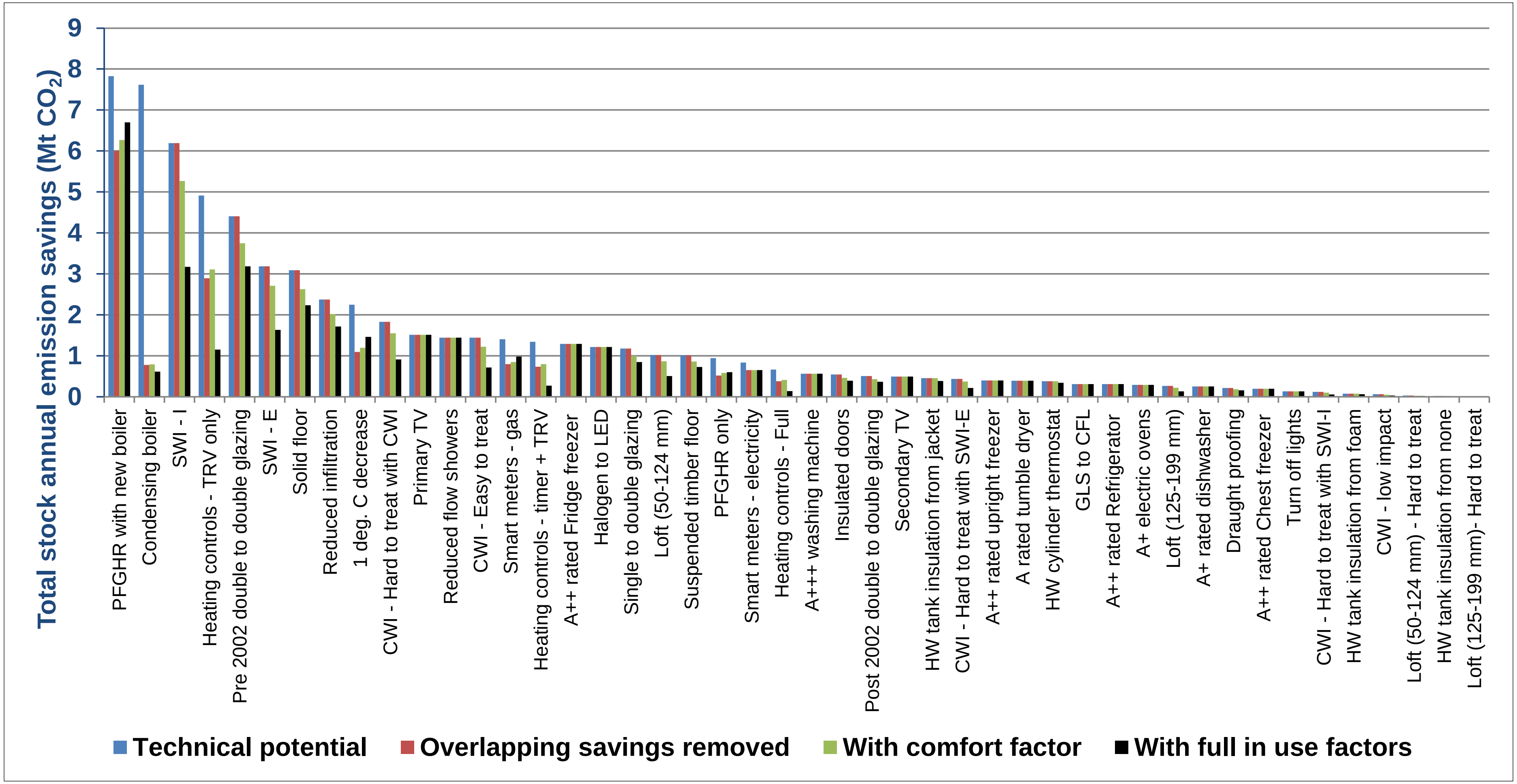


Figure 14 Total potential for measures savings across stock with incremental inclusion of in use factors

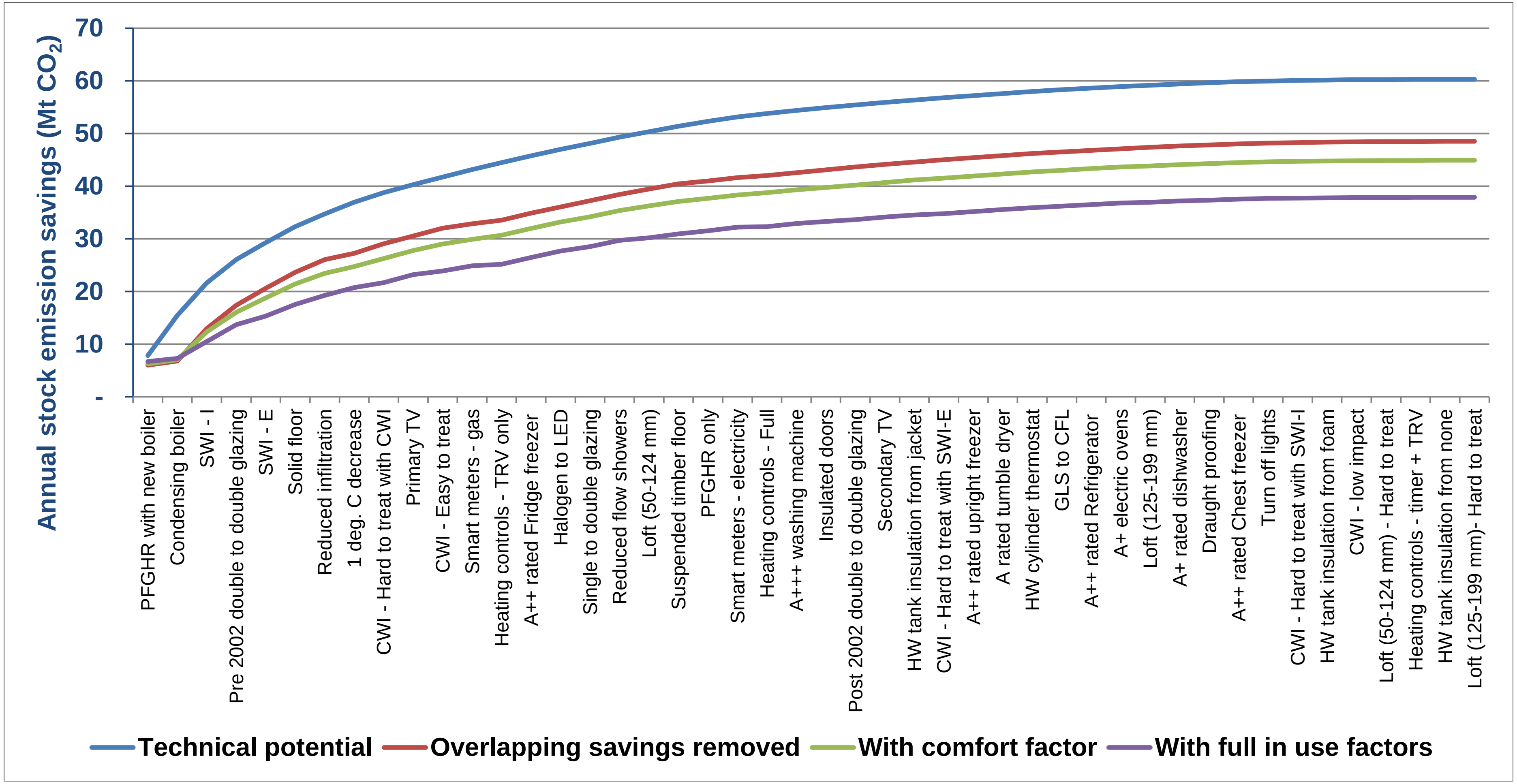


Figure 15 Cumulative potential for emission savings by measures across stock with incremental inclusion of in use factors

8 The Marginal Abatement Cost Curves (MACC)

8.1 MACC methodology

The MACC model uses the energy savings identified across the UK building stock, the heating fuel type to determine the annual fuel bill (£) and annual emission (tCO_2) savings. The fuel bill savings are based on the DECC long run variable fuel costs for fossil fuels, while electricity costs are based on the average of the long run marginal cost of nuclear and onshore wind generation under CCC projections. The measure fixed and marginal cost of installation and the measure lifetime is used to determine the annualised cost of installation in individual house types. The cost effectiveness of the measures is then calculated as:

$$\text{Cost effectiveness of measure } (£/\text{t CO2}) = \frac{\text{Annualsied cost of measure installation } (£) - \text{ Annual fuel bill savings } (£)}{\text{Annual CO2 savings (t)}}$$

The annualised installation costs, annual fuel bill savings (£) and the CO_2 savings (t) are then aggregated across the whole UK stock for each measure to calculate its average cost effectiveness across the whole domestic stock. The measures are then sorted by their cost effectiveness in ascending order to generate the MACC outputs.

8.2 The MACC Outputs

The MACC outputs are generated including all the thermal measures, electrical appliances and behavioural changes. The electrical appliances, energy efficient lighting and boiler replacement show negative cost effectiveness due to having no incremental cost attributed to them, as they are end of lifetime replacement measures. The additional cost of the best energy rating appliance is negligible compared to the conventional replacement technology and in most cases regulation means that there is no low efficiency alternative e.g. condensing boilers, CFL lighting. For all other measures, the full installation cost is considered in the calculation of the annualised capital cost. Amongst the thermal measures, easy to treat CWI, loft insulation in homes with existing loft thickness of 0-49mm, hot water cylinder insulation and heating controls (TRV) show favourable economics with the fuel savings paying back for the installation costs over their lifetime (discounted at 3.5%). However with the inclusion of full in use factors, measures such as heating controls, HW cylinder thermostat and loft (125-199mm) are no longer economic due to reduced savings. The measures with high cost of emission reduction but with significant potential for savings include SWI (internal and external), double glazing, reduced infiltration and solid floor insulation. The detailed MACC outputs and the performance of individual measures are shown below:

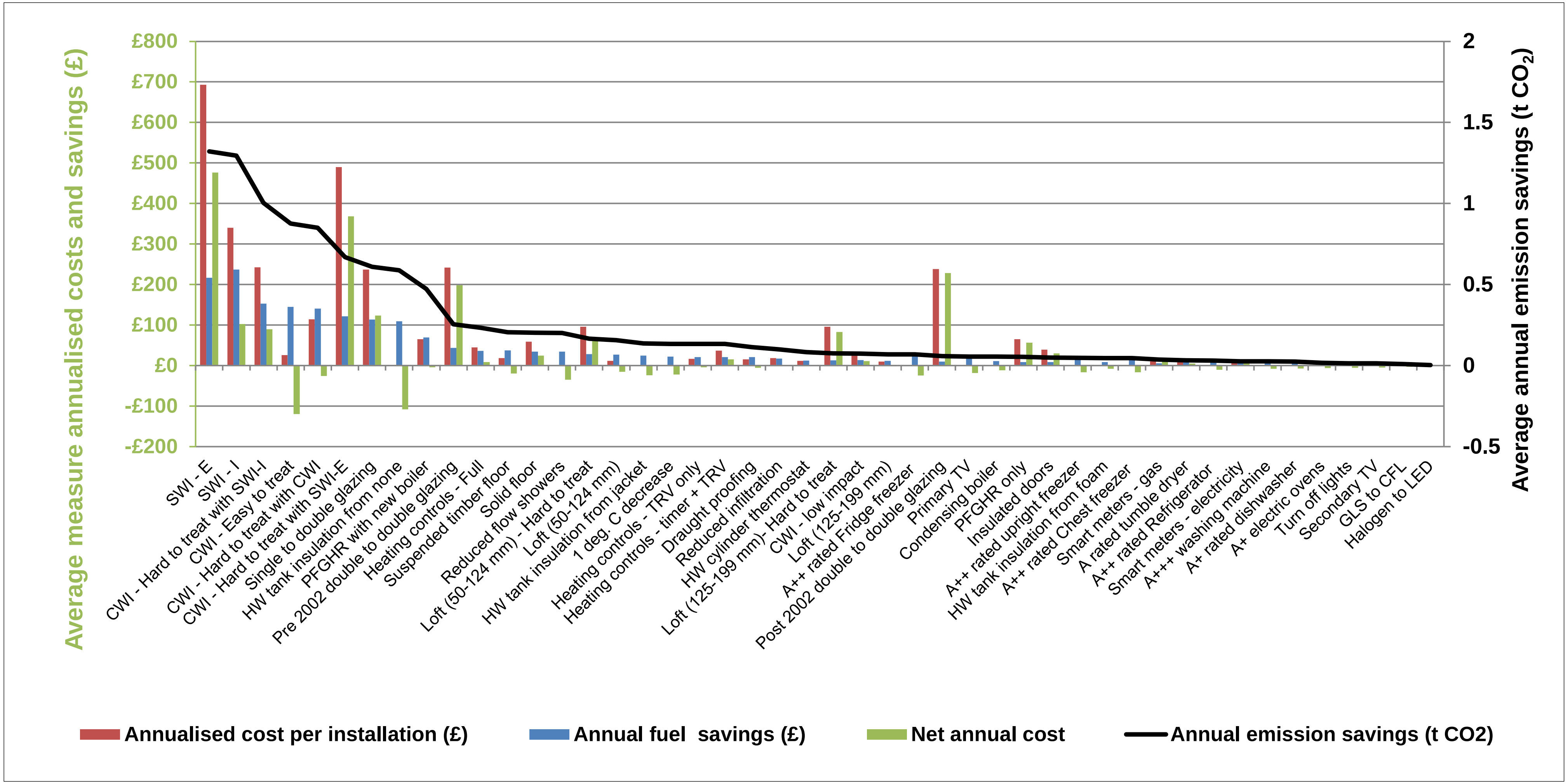


Figure 16 Breakdown of weighted average cost, annual fuel (£) and emission (t CO_2) savings by measure (no IUF applied)

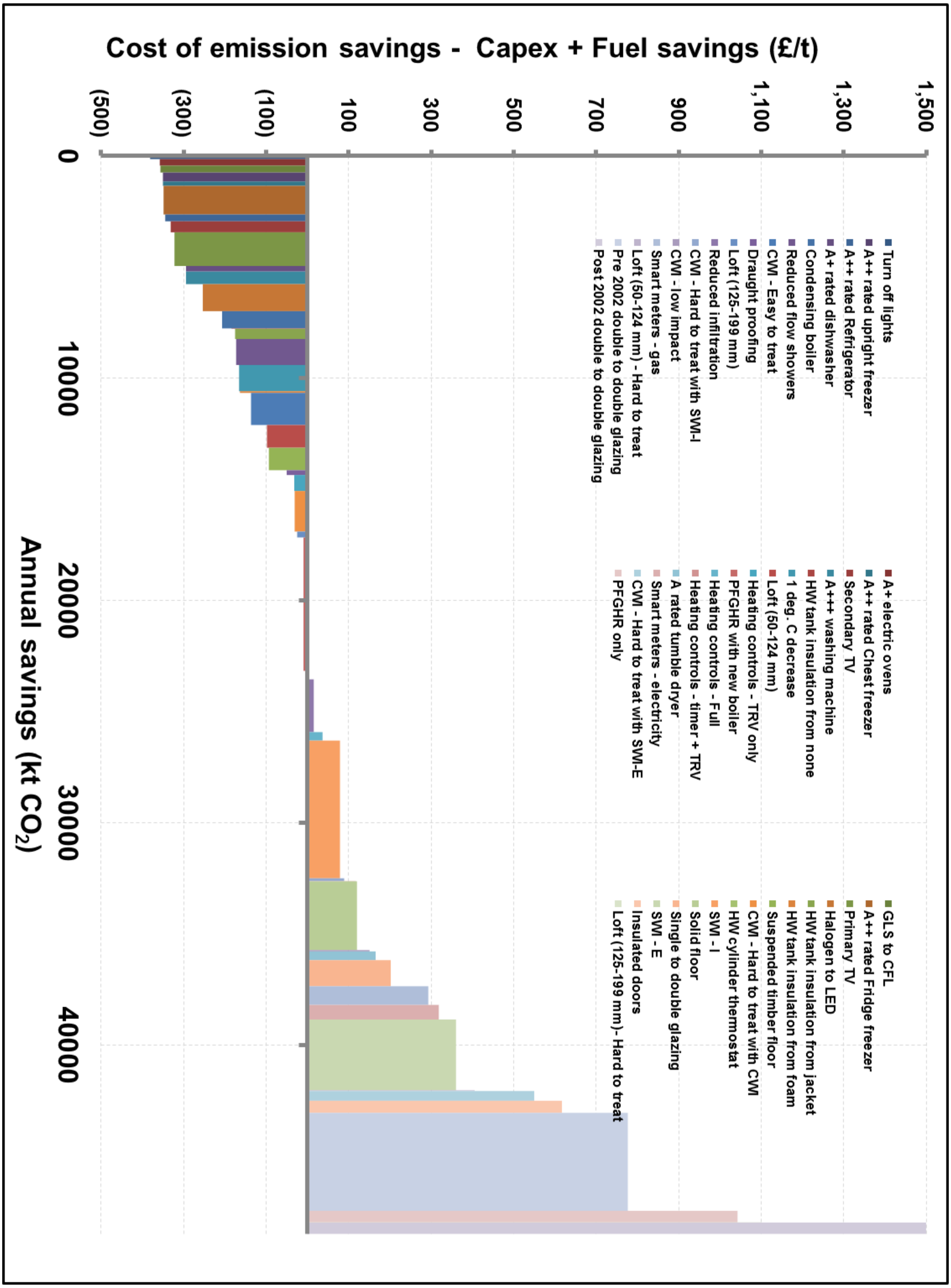


Figure 17 MACC based on total potential without in use factors (overlapping savings removed)

Table 8 Measure technical potential for savings and cost effectiveness without in use factors (overlapping savings removed)

Measure	Total annual savings of UK stock (kt CO_2)	Cost effectiveness (£/t CO_2)
Turn off lights	134	-£381
A+ electric ovens	295	-£357
GLS to CFL	313	-£356
A++ rated upright freezer	400	-£350
A++ rated Chest freezer	195	-£350
A++ rated Fridge freezer	1,290	-£348
A++ rated Refrigerator	308	-£344
Secondary TV	492	-£331
Primary TV	1,516	-£322
A+ rated dishwasher	252	-£294
A+++ washing machine	565	-£294
Halogen to LED	1,218	-£253
Condensing boiler	777	-£206
HW tank insulation from none	16	-£184
HW tank insulation from jacket	458	-£175
Reduced flow showers	1,170	-£172
1 deg. C decrease	1,180	-£165
HW tank insulation from foam	77	-£163
CWI - Easy to treat	1,441	-£136
Loft (50-124 mm)	1,023	-£97
Suspended timber floor	1,012	-£93
Draught proofing	216	-£50
Heating controls - TRV only	718	-£31
CWI - Hard to treat with CWI	1,829	-£30

Loft (125-199 mm)	263	-£24
PFGHR with new boiler	6,001	-£9
HW cylinder thermostat	383	-£5
Reduced infiltration	2,377	£16
Heating controls - Full	381	£37
SWI - I	6,195	£79
CWI - Hard to treat with SWI-I	120	£89
Heating controls - timer + TRV	18	£118
Solid floor	3,091	£121
CWI - low impact	62	£151
A rated tumble dryer	390	£166
Single to double glazing	1,176	£202
Smart meters - gas	841	£294
Smart meters - electricity	654	£319
SWI - E	3,185	£361
Loft (50-124 mm) - Hard to treat	33	£406
CWI - Hard to treat with SWI-E	437	£550
Insulated doors	547	£617
Pre 2002 double to double glazing	4,407	£777
PFGHR only	520	£1,043
Loft (125-199 mm)- Hard to treat	8	£1,101
Post 2002 double to double glazing	510	£3,886

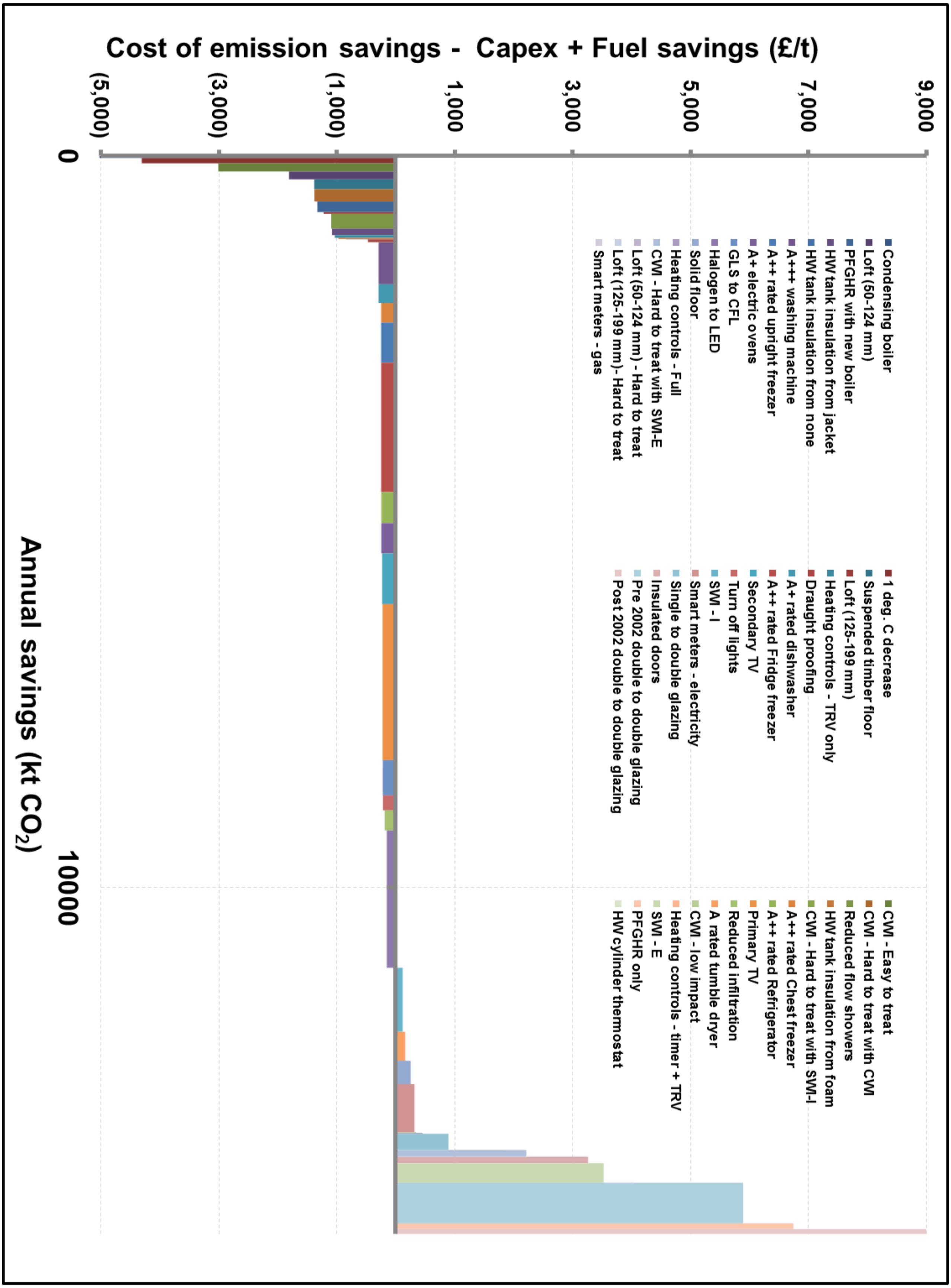


Figure 18 MACC based on total potential in traded sector without in use factors (overlapping savings removed)

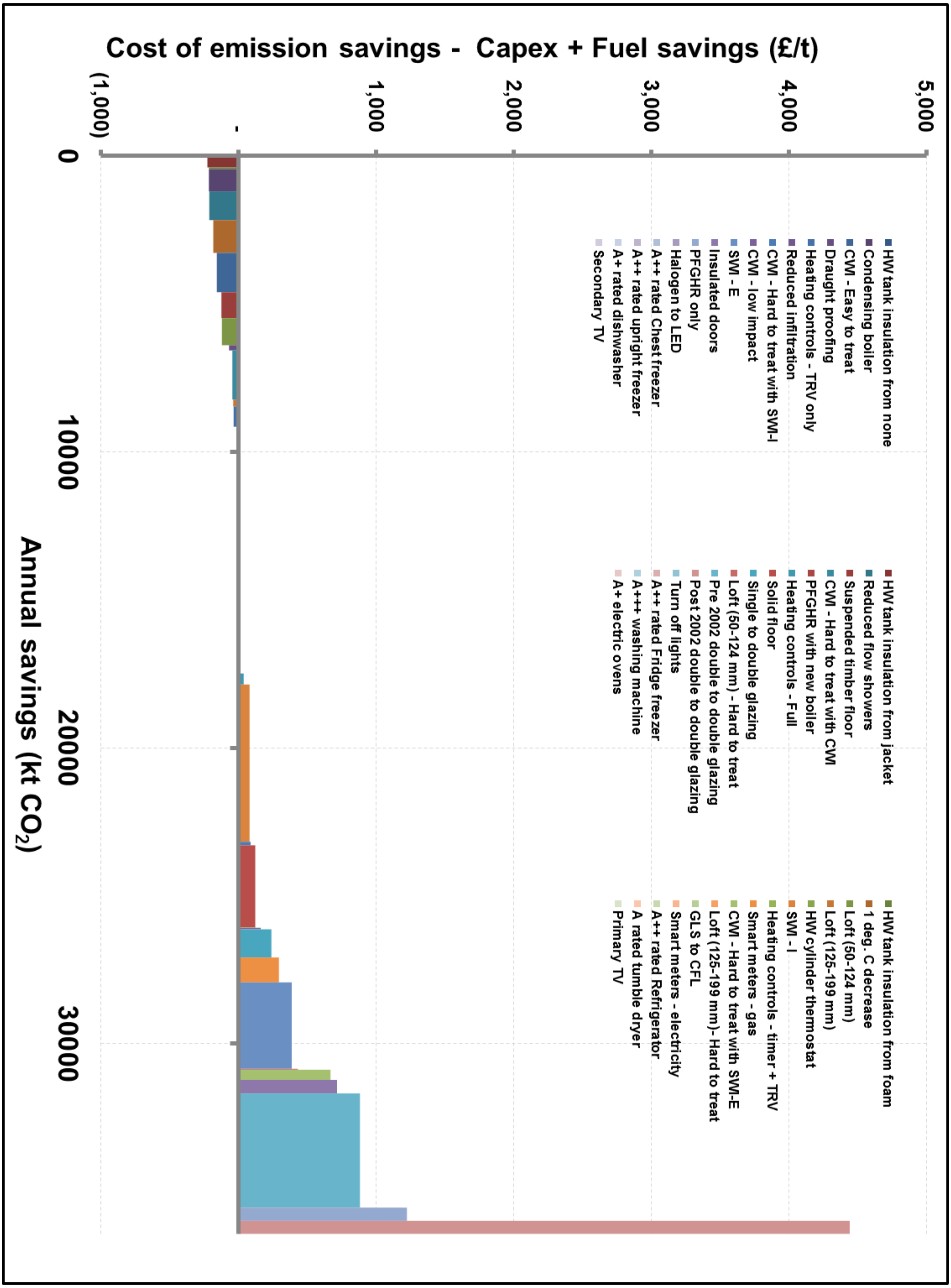


Figure 19 MACC based on total potential in non-traded sector without in use factors (overlapping savings removed)

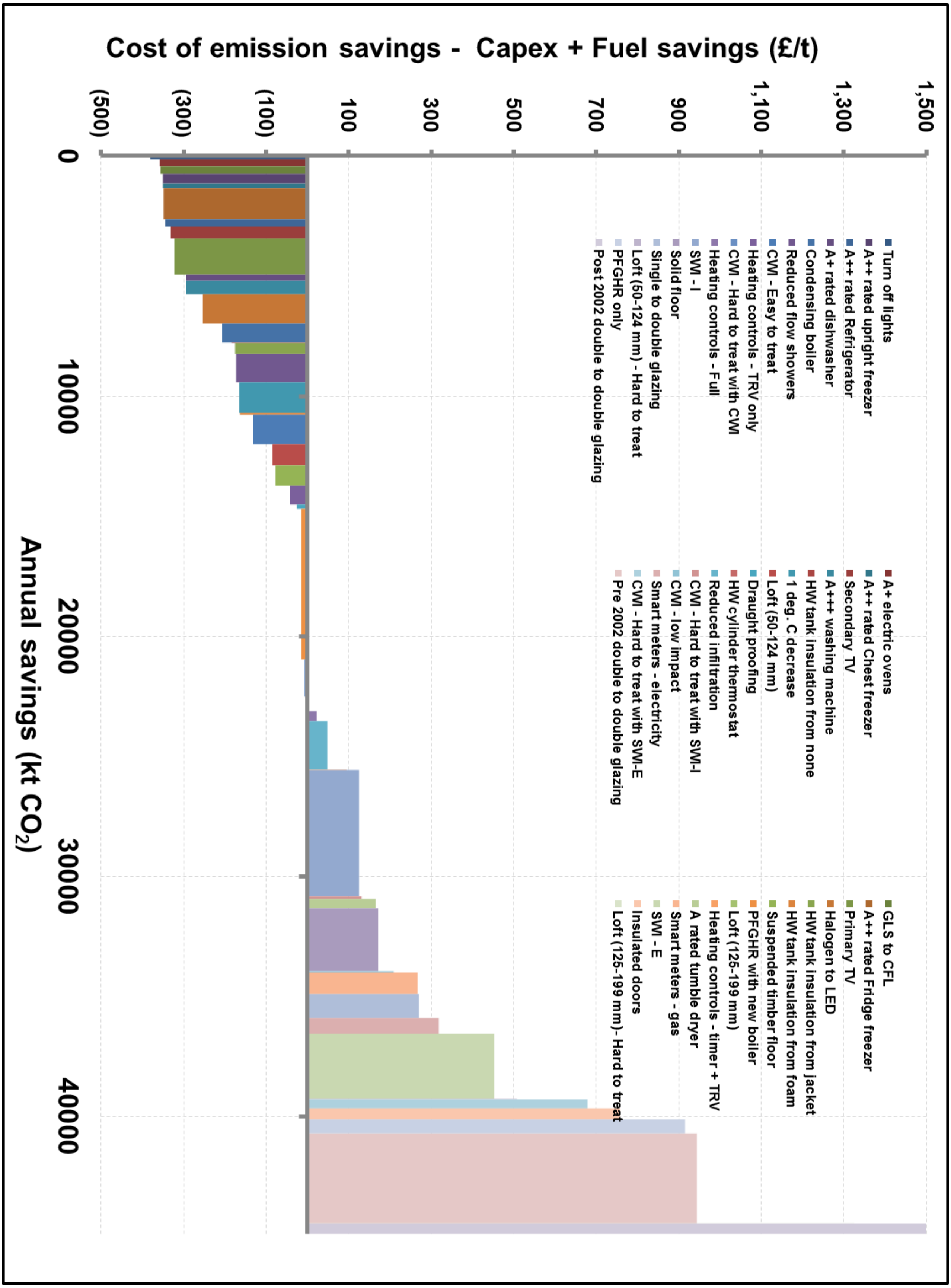


Figure 20 MACC based on total potential with comfort factor included (overlapping savings removed)

Table 9 Measure technical potential for savings and cost effectiveness with comfort factor included (overlapping savings removed)

Measure	Total annual savings of UK stock (kt CO_2)	Cost effectiveness (£/t CO_2)
Turn off lights	134	-£381
A+ electric ovens	295	-£357
GLS to CFL	313	-£356
A++ rated upright freezer	400	-£350
A++ rated Chest freezer	195	-£350
A++ rated Fridge freezer	1,290	-£348
A++ rated Refrigerator	308	-£344
Secondary TV	492	-£331
Primary TV	1,516	-£322
A+ rated dishwasher	252	-£294
A+++ washing machine	565	-£294
Halogen to LED	1,218	-£253
Condensing boiler	791	-£206
HW tank insulation from none	16	-£184
HW tank insulation from jacket	458	-£175
Reduced flow showers	1,170	-£172
1 deg. C decrease	1,288	-£165
HW tank insulation from foam	77	-£163
CWI - Easy to treat	1,225	-£131
Loft (50-124 mm)	869	-£84
Suspended timber floor	860	-£77
Heating controls - TRV only	781	-£42
Draught proofing	184	-£25
PFGHR with new boiler	6,266	-£15

CWI - Hard to treat with CWI	1,554	-£7
HW cylinder thermostat	383	-£5
Loft (125-199 mm)	224	£1
Heating controls - Full	412	£23
Reduced infiltration	2,020	£49
Heating controls - timer + TRV	20	£96
SWI - I	5,266	£126
CWI - Hard to treat with SWI-I	102	£132
A rated tumble dryer	390	£166
Solid floor	2,628	£172
CWI - low impact	52	£210
Smart meters - gas	894	£267
Single to double glazing	1,000	£271
Smart meters - electricity	654	£319
SWI - E	2,707	£453
Loft (50-124 mm) - Hard to treat	28	£508
CWI - Hard to treat with SWI-E	372	£679
Insulated doors	465	£758
PFGHR only	581	£916
Pre 2002 double to double glazing	3,746	£944
Loft (125-199 mm)- Hard to treat	7	£1,325
Post 2002 double to double glazing	433	£4,602

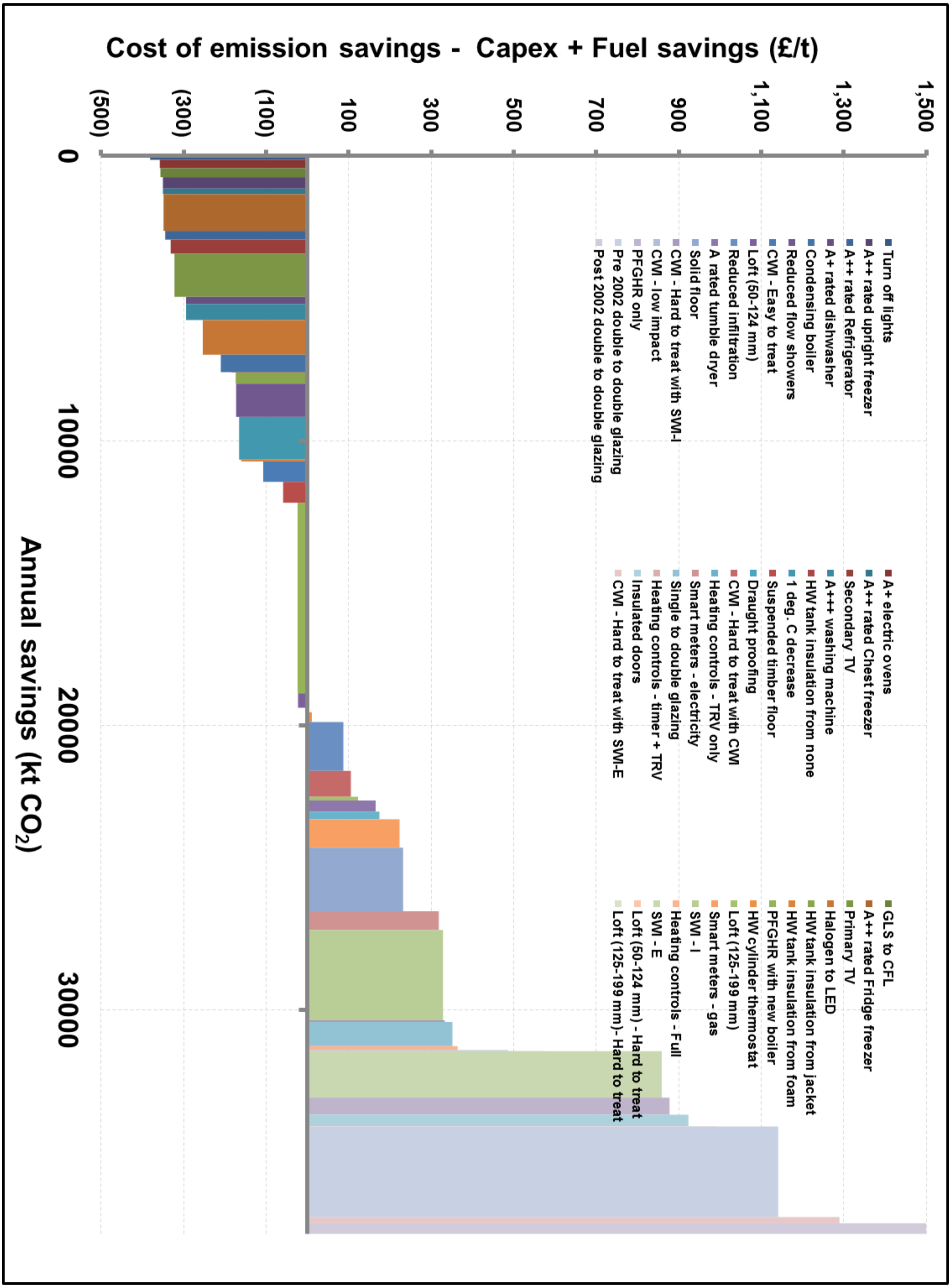


Figure 21 MACC based on total potential with full in use factors included (overlapping savings removed)

Table 10 Measure technical potential for savings and cost effectiveness with full in use factors included (overlapping savings removed)

Measure	Total annual savings of UK stock (kt CO_2)	Cost effectiveness (£/t CO_2)
Turn off lights	134	-£381
A+ electric ovens	295	-£357
GLS to CFL	313	-£356
A++ rated upright freezer	400	-£350
A++ rated Chest freezer	195	-£350
A++ rated Fridge freezer	1,290	-£348
A++ rated Refrigerator	308	-£344
Secondary TV	492	-£331
Primary TV	1,516	-£322
A+ rated dishwasher	252	-£294
A+++ washing machine	565	-£294
Halogen to LED	1,218	-£253
Condensing boiler	614	-£209
HW tank insulation from none	14	-£183
HW tank insulation from jacket	389	-£174
Reduced flow showers	1,170	-£172
1 deg. C decrease	1,499	-£165
HW tank insulation from foam	66	-£160
CWI - Easy to treat	717	-£107
Suspended timber floor	731	-£59
PFGHR with new boiler	6,697	-£23
Loft (50-124 mm)	509	-£22
Draught proofing	156	£3
HW cylinder thermostat	345	£11

Reduced infiltration	1,717	£88
CWI - Hard to treat with CWI	909	£106
Loft (125-199 mm)	131	£123
A rated tumble dryer	390	£166
Heating controls - TRV only	267	£175
Smart meters - gas	1,000	£224
Solid floor	2,233	£232
Smart meters - electricity	654	£319
SWI - I	3,175	£329
CWI - Hard to treat with SWI-I	60	£334
Single to double glazing	849	£352
Heating controls - Full	140	£365
CWI - low impact	31	£487
Heating controls - timer + TRV	7	£577
SWI - E	1,632	£859
PFGHR only	601	£878
Insulated doors	395	£924
Loft (50-124 mm) - Hard to treat	17	£989
Pre 2002 double to double glazing	3,184	£1,141
CWI - Hard to treat with SWI-E	217	£1,290
Loft (125-199 mm)- Hard to treat	4	£2,386
Post 2002 double to double glazing	368	£5,444

9 Appendix

9.1 Cavity wall insulation potential

Calculating total numbers of Hard to Treat Cavity walls

A large number of the homes in the EHS, SHCS and Living in Wales surveys could be put in to two or more of the available wall type categories. For example, approximately 120,000 homes in the Narrow cavity category are also listed as having wall faults.

The following hierarchy was used to ensure that homes in the survey were placed in to one category only.

Limited potential Hard to treat

V

Limited potential

V

Narrow cavity

V

Concrete / Metal / Timber frame

V

Wall Fault

V

Greater than 3 stories

V

Exposed location

V

Random stone

V

Standard easy to treat cavity

Please note that, although this approach has the advantage of more accurately quantifying hard to treat cavities in total, it makes the results less useful in quantifying the relative potential for each hard to treat cavity type as categories at the top of the hierarchy are represented more accurately than those at the bottom of the hierarchy.

The total number of each hard to treat cavity wall type before taking in to account the overlap between categories is provided in the table below:

Wall type	Description	Potential (ignoring overlap between categories) GB only 2008	Potential (taking in to account overlap between categories)	Stock (%)
Solid walls	Solid Wall (un-insulated)		7,194,436	26%
	Solid wall (insulated)		209,000	1%
Insulated Cavities or equivalent U-value	Insulated cavities (+ 5% Pre 1990 Un-insulated)		13,342,659	48%
	Insulated or equivalent (Post 1990)		1,365,700	5%
Empty cavities with limited potential for improvement	Standard cavities with Limited potential for improvement 1980 - 1990 (easy to treat)		838,920	3%
	Hard to treat cavities with Limited potential for improvement (1980 – 1990) plus un-insulatable timber frame dwellings with insulation between the studwork		369,881	1%
Standard empty cavities	Not insulated Easy to treat		1,644,482	6%
	Total Hard to Treat cavities*	3,617,031	2,924,923	10%
Hard to fill empty cavities	Hard to treat: Narrow	505,853	474,989	2%
	Hard to treat: Concrete frame	506,153	524,889	2%
	Hard to treat Metal Frame	74,651	62,888	0%
	Hard to treat Timber frame (un-insulated studwork with masonry cavity)	69,159	65,483	0%
	Hard to treat: Wall fault	1,642,354	1,386,191	5%
	Hard to treat: Too high (greater than 3 stories)	418,861	91,091	0%
	Hard to treat: Exposed Location	225,000	199,953	1%
	Hard to treat: Random stone	175,000	119,438	0%
	Total		27,890,000	100%

Approximately 120,000 narrow cavities are also listed as having wall faults in the GB housing surveys. Approximately 170,000 homes listed as being 3 stories of greater are also classified as being a hard to treat cavity due to being of concrete, metal or timber frame construction.

Notes on the differences between EST and DECC analysis

The EST estimates differ from the DECC potentials for wall insulation, particularly in the area of easy to treat vs hard to treat cavity walls. The differences between the two estimates are presented below:

				DECC April 2013	**EST April 2013**
Insulated	**Insulated**			**10,450,000**	**13,342,659**
	Insulated or equivalent			**2,920,000**	**1,365,700**
Uncertainty				**470,000**	
Remaining potential	Limited potential	**Easy to treat**		**940,000**	**838,920**
		Hard to treat		**500,000**	**369,881**
	Not insulated	**Easy to treat**		**740,000**	**1,644,482**
		Hard to treat	Narrow	535,000	474,989
			Concrete	555,000	524,889
			Random Stone	175,000	119,438
			Metal Construction	110,000	62,888
			Timber (has cavity)	103,000	65,483
			Wall Fault	1,350,000	1,386,191
			Too high	66,500	91,091
			Exposed location	225,000	199,953
			Total Not Insulated Hard to Treat	**3,120,000**	**2,924,923**

Solid walls			**Insulated Solid wall**	**205,000**	**209,000**
			Uncertainty (Solid wall)	**126,000**	
			Un-insulated solid wall	**7,660,000**	**7,194,436**
			Total properties	**26,661,000**	**27,890,000**

In addition to the specific reasons for the divergence listed in the methodology above, there are a number of other general reasons why the EST analysis would be expected to yield different results to the DECC quarterly insulation potentials;

1. The DECC estimates for hard to treat cavity wall numbers are based on the figures provided in the Inbuilt 2012 report on hard to treat cavity walls. This report provides a range for the likely number of dwellings in each individual hard to treat category. In calculating the Quarterly Insulation potentials, DECC assumes the mid-point of these ranges as being the most likely number of hard to treat cavity walls in each category and assumes that each hard to treat category is additional with no overlap between them. These mid-points mirror closely the EST estimates for Hard to treat cavity wall categories before overlap between them is taken in to account as provided in the above table. The EST analysis looks at the overlap between the hard to treat types and therefore arrives at a lower estimate of hard to treat cavity walls overall. This is despite the fact that in certain cases, more hard to treat cavity wall are identified in each individual category (for example by including all dwellings over three stories, as opposed to all dwellings over four stories).
2. In a number of cases, hard to treat cavity walls as classified by Inbuilt could also be classified as solid walls by the housing surveys. This is particularly the case for concrete, metal and timber frame construction. Therefore, we believe there is an overlap between the hard to treat cavity wall numbers and the solid wall numbers in the DECC analysis.
3. DECC adds 5% of un-insulated cavity walls to the insulated column and puts an additional 5% of un-insulated cavities in to the uncertainty columns. EST does not think it necessary to allow for 10% inaccuracy in the housing surveys due to the creation of the limited potential and insulated or equivalent columns which already remove a large amount of the potential for non-identification of cavity wall insulation.
4. In the DECC quarterly insulation potentials, the Northern Ireland stock is assumed to mirror the mix of wall types in the UK stock and these number are applied proportionally to the Northern Ireland housing stock. The EST analysis used data from the 2011 Northern Ireland housing survey which shows a greater proportion of insulated cavities than the UK stock as a whole.
5. The DECC analysis also assumes that there are no additional hard to treat cavities in Northern Ireland whereas the EST analysis applies a proportional increase in hard to treat cavity wall numbers based on the Northern Ireland housing stock numbers.

6. The EST analysis uses the latest Ofgem definition of Hard to treat cavities – too tall which is a cavity wall greater than 3 stories. DECC uses a definition of too tall as being 4 stories or greater.

The table below describes in detail the methodology for each category of wall type making reference to any differences to the DECC methodology.

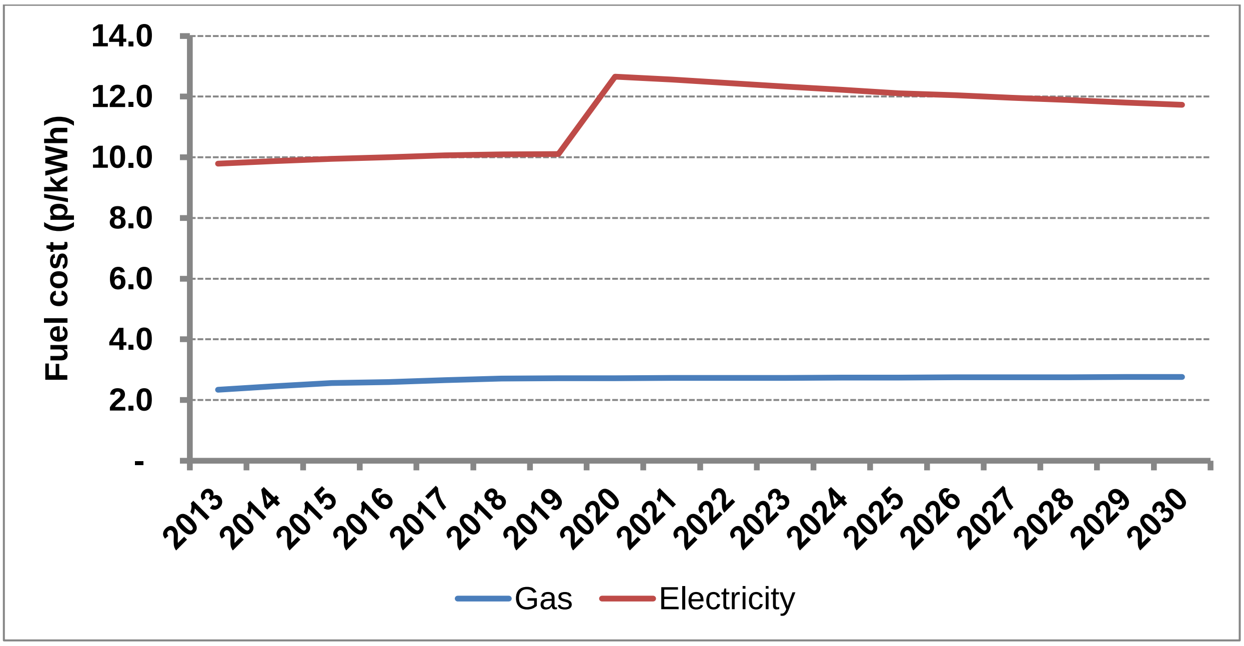
Measure	DECC methodology	EST methodology	Explanation for difference
Insulated cavity wall	All pre 1996 (1992 in Scotland) properties listed as having cavity wall insulation in the GB housing surveys + 5% additional Pre 1996 cavities	All properties listed as having a cavity wall in the GB housing surveys + 5% additional Pre 1990 cavities 840,000 new build dwellings post 2008 all assumed to be Insulated Cavity	1996 age band does not exist in the EHS. Not clear how DECC applied this age band to the housing survey age bands.
Insulated or meets equivalent standard	All post 1995 properties (post 1991 in Scotland) assumed to meet a U-value of 0.45 or better 840,000 new build dwellings post 2008 all assumed to be Insulated Cavity	All post 1990 properties assumed to meet a U-value of 0.45 or better	1996 age band does not exist in the EHS. Not clear how DECC applied this age band to the housing survey age bands.
Uncertainty	Based on the BRE recommendation of 5-10% under-reporting of insulated cavities in the EHS, DECC apply an additional 5% uncertainty to all pre 1996 empty cavities (the other 5% is accounted for in the 'Insulated Cavity' category).	Category removed.	The BRE recommendation of 5 - 10% adjustment of the Insulated cavity potential was suggested to account for the difficulty of surveyors identifying cavity wall insulation, particularly in dwellings with cavities filled during construction. 5% of this uncertainty is already accounted for in the 'Insulated Cavity' category. The remainder of the uncertainty is assumed to have been eliminated by the creation of the 'Insulated or meets equivalent standard' and 'Limited potential' categories which already accounts for any post 1980 properties listed as 'un-insulated'. EST's view is that to remove Post 1980s empty cavities from the

			'Empty cavity' category and to remove an additional 5% as uncertainty, is to double count the BRE recommended adjustment.
Limited potential (easy to treat)	Properties built between 1983 and 1995 (1984 – 1991 in Scotland) assumed to have a U-value of 0.6	Properties built between 1980 and 1990 assumed to have a U-value of 0.6	Age bands used by DECC are not available in the EHS. Not clear how DECC applied this age band to the housing survey age bands.
Easy to treat	All Pre 1983 properties recorded as un-insulated (less 10% for BRE recommendation (5% included in insulated, 5% included in uncertainty)	All pre 1980 properties recorded as un-insulated less 5% for BRE recommendation (included in insulated)	Age bands used by DECC are not available in the EHS. Not clear how DECC applied this age band to the housing survey age bands.
Limited potential (hard to treat)	All timber frame cavities listed with insulation between the studwork + an estimate of 'partial fill' cavities.	All timber frame cavities with insulation between the studwork. Partial fill cavities are included in the 'insulated cavity' column.	Data unavailable within the housing surveys on partial fill as opposed to full fill.
Hard to treat: Narrow	20% of empty cavity walls 1920 – 1944 5% of empty cavity walls 1945 - 1993 Does not apply in Scotland	20% of empty cavity walls 1920 – 1944 5% of empty cavity walls 1945 - 1990 Does not apply in Scotland	
Hard to treat: Concrete	Listed in housing survey as being: - Concrete Construction - Not in-situ concrete unless it has maisonry pointing (implying the existence of a cavity) - Not Crosswall construction - Not built post 1993 - Not insulated	Listed in housing survey as being: - Concrete Construction - Not in-situ concrete unless it has maisonry pointing (implying the existence of a cavity) - Not Crosswall construction - Not built post 1990 - Not insulated	
Hard to treat:	- In an area noted by the British Geological Survey	- None in Wales - Listed by a housing	

Random Stone	as using random stone cavity construction - None in Wales - Listed by a housing survey as having; - Masonry construction in England - In a BGS local authority - Stone Construction in Scotland - Built prior to 1993, Not a flat - Not solid wall - Not insulated - Not in an urban location	survey as having; - Masonry construction in England - Stone Construction in Scotland - Built prior to 1990, Not a flat - Not solid wall - Not insulated - Not in an urban location	
Hard to treat: Metal Construction	- Listed as Metal construction in a housing survey - Not Post 1993 - Not insulated	- Listed as Metal construction in a housing survey - Not Post 1990 - Not insulated	
Hard to treat: Timber frame (un-insulated studwork) with masonry cavity	- Timber frame - Built pre 1979 - Not identified as having insulation in the studwork - Cavity wall construction (Scotland) - Masonry Pointing (England and Wales)	- Timber frame - Built pre 1979 - Not identified as having insulation in the studwork - Cavity wall construction (Scotland) - Masonry Pointing (England and Wales)	
Hard to treat: Wall fault	- Unfit or defective walls (Wales) - Urgent repair required for wall finish or penetrative damp (Scotland) - Unfit or defective walls (England)	- Unfit or defective walls (Wales) - Urgent repair required for wall finish or penetrative damp (Scotland) - Unfit or defective walls (England)	
Hard to treat: Too High	- Greater than 4 stories	Greater than 4 stories	
Hard to treat: Exposed Location	- Located in Exp Zone 3 but local conditions accentuate exposure - Located in Exp Zone 4 and local conditions do not protect from Exposure	- Located in Exp Zone 3 but local conditions accentuate exposure - Located in Exp Zone 4 and local conditions do not protect from Exposure	

9.2 Fuel cost and CO_2 content[42]

Fuel	2013 central cost (p/kWh)	CO_2 content (kg/kWh)
Gas	2.34	0.18
Electricity	9.79	0.38
Oil	5.16	0.24
Coal	3.26	0.33



[42] Electricity cost and CO_2 content provided by CCC
Fossil fuel costs and CO_2 content based on DECC central scenario

9.3 Weighted average installation costs, lifetime fuel (£) and emission savings (t CO_2)

The installation costs of the measures depend on the house type attributes such as wall area, loft area and thickness, glazing area etc. This gives a variation of installation costs and performance (annual fuel (£) and emission (t CO_2) savings). The weighted average cost and savings from measure across the total UK stock is presented below:

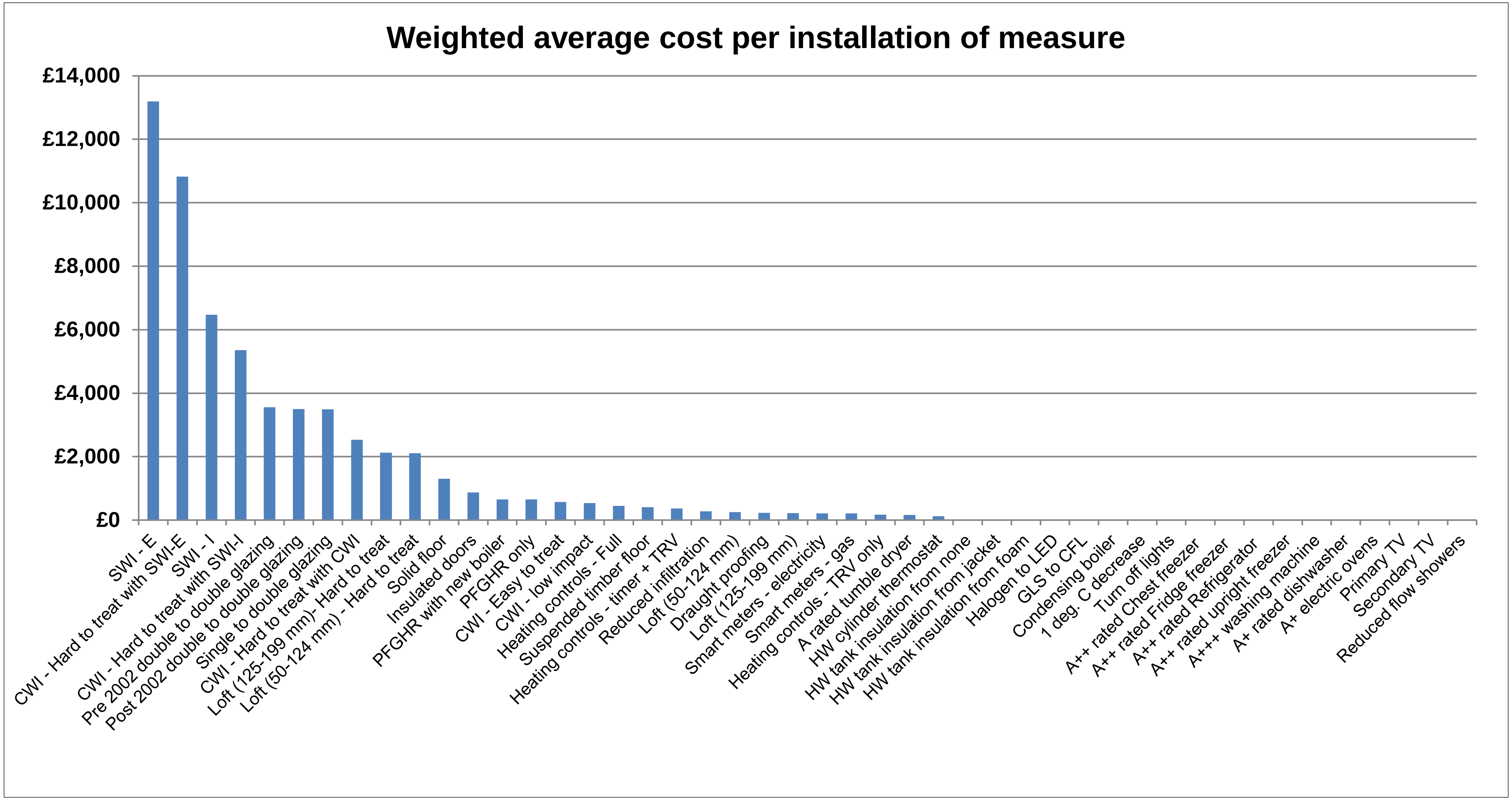


Figure 22 Breakdown of weighted average cost of installation of measures

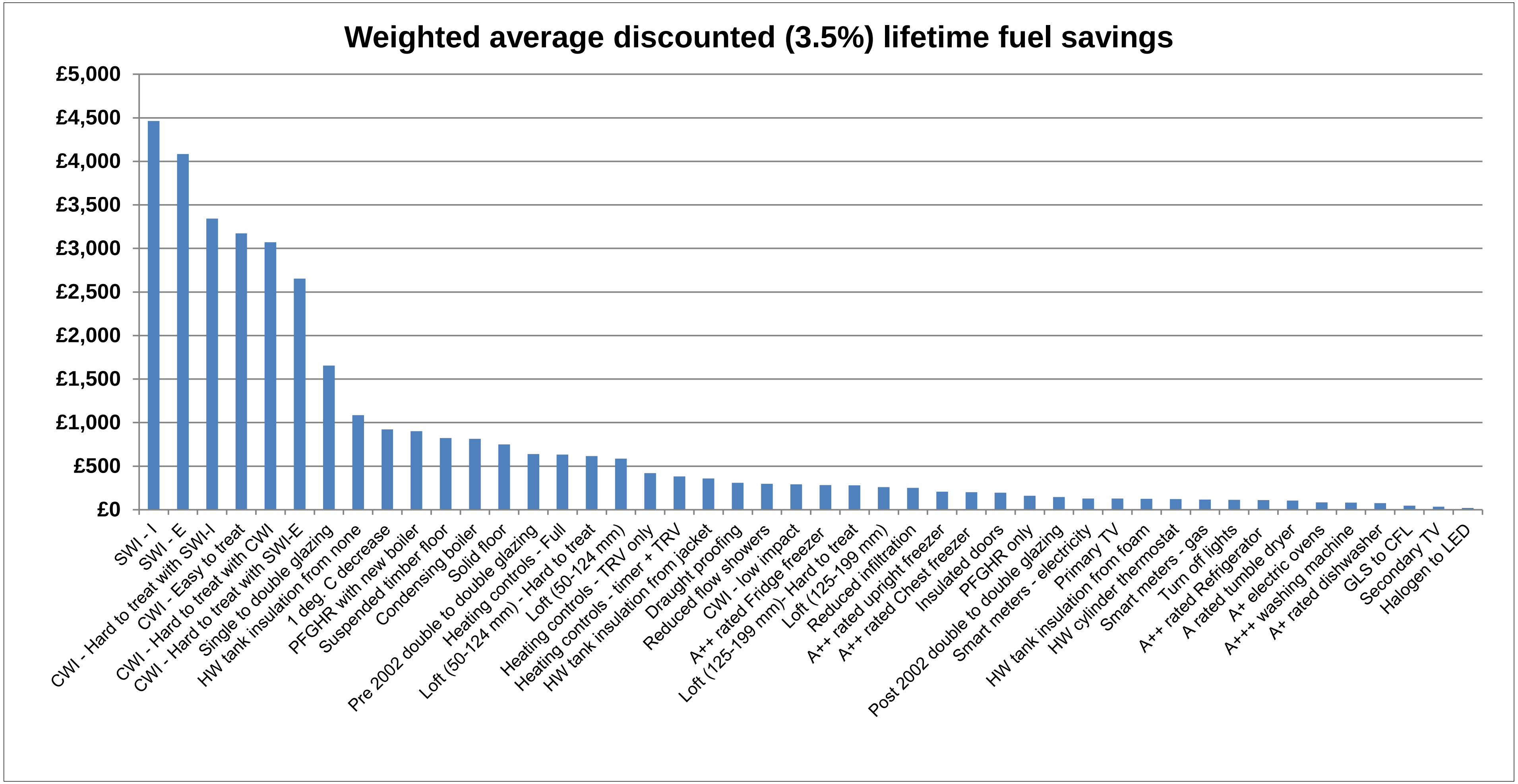


Figure 23 Breakdown of weighted average discounted (3.5%) lifetime fuel savings (£)

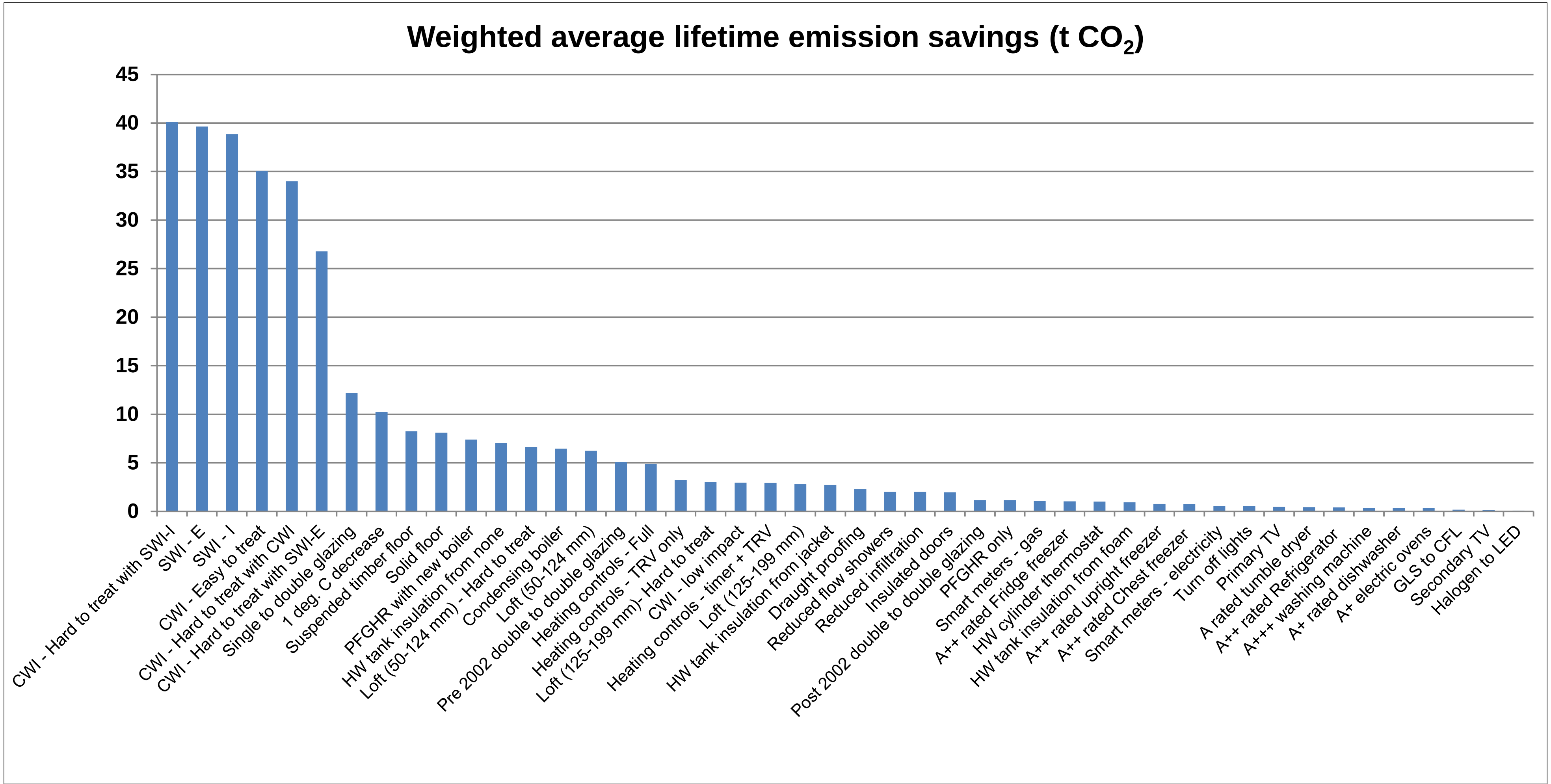


Figure 24 Breakdown of weighted average lifetime emission savings (t CO_2)