element energy

Uptake of energy efficiency in buildings

On behalf of

Committee on Climate Change

Final Report
11/08/2009

element energy

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INTRODUCTION

In its recent report[1] the Committee on Climate Change (CCC) brought together an extensive evidence base to produce the first carbon budgets for the UK. As part of this evidence base the CCC commissioned work to assess the maximum technical potential CO_2 savings of a range of energy efficiency measures in buildings across the domestic, non-domestic and industrial sectors. In 2007 energy consumption in buildings and industry accounted for 70% of UK total emissions and were just under 400MtCO_2 per annum.

This December report found remaining technical potentials for low or zero cost energy efficiency measures in the domestic, non-domestic and industrial sectors of 40Mt, 11Mt, and 7Mt of annual CO_2 savings respectively. Realistically the following reductions were considered achievable by 2020 from energy efficiency measures for existing buildings:

- 9-18MtCO_2 per annum for the residential sector,
- 5-9 MtCO_2 per annum for the non-domestic sector
- 4 -6 MtCO_2 per annum for the industrial sector.

The upper and lower bounds in these figures represent the current and stretch budgets for the CCC. These figures were derived from work by the Buildings Research Establishment (BRE) and AEA to establish marginal abatement cost curves (MACCs) for the emissions reduction potential. This work identified significant uncertainty, however, around the realistic uptake trajectories and failed fully to explain the failure thus far of households to adopt negative cost energy efficiency improvements.

To further develop this analysis, the CCC commissioned Element Energy to develop trajectories for the uptake of various energy efficiency measures in the first budget period to 2022.

The scope of this work is as follows:

- Review the evidence base in this sector with respect to potential capacities, supply and demand side barriers, and effective policy measures.

- Use this to develop robust, evidence based scenarios for the uptake of each technology, accounting for barriers and assessing the potential impact of policies aimed at increasing the rate of uptake. We will provide suggested actions to increase deployment if targets are not met (or are revised upwards) in the future

This report considers the existing stock of homes only, given that it is estimated that 99% of homes will still be present in 2020 and these will form 88% of the housing stock. The remaining new-build is already covered by strict legislation and is already 70% more efficient than those built prior to 1990.

METHODOLOGY

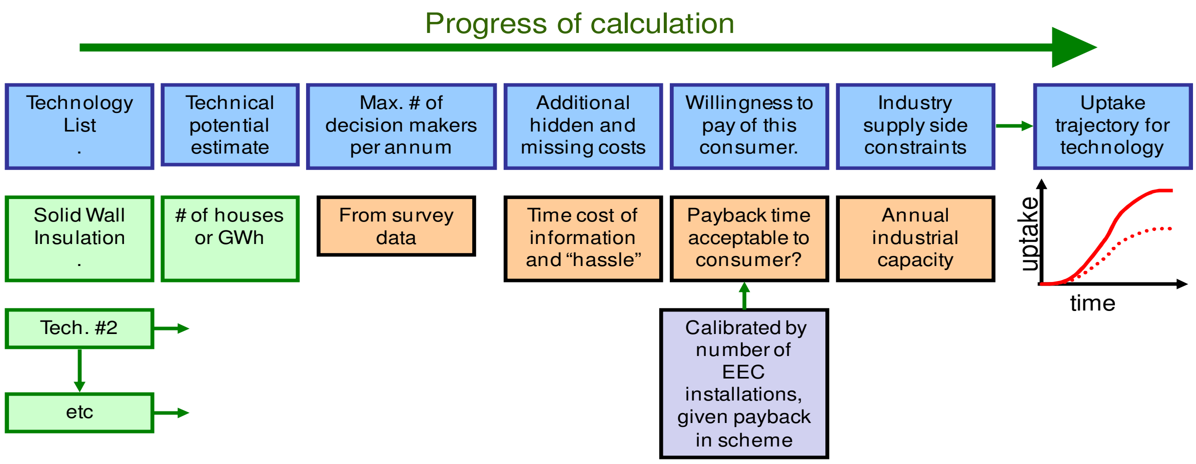
This approach differs from the methodology used in prior work for the CCC undertaken by BRE, whereby an s-curve was fitted to Energy Efficiency Commitment (EEC) and Carbon Emission Reduction Target (CERT) estimates or historical uptake figures. While likely to be accurate in the near term, that approach does not consider the consumer decision-making process in detail and does not enable predictions of future uptake if policy conditions are altered. This document examines the decision process to analyse the most effective policies to achieve a given target for uptake.

Previous work analysing the realistic potential for energy efficiency measures has frequently failed to explain the discrepancy between observed uptake and uptake predicted from financial cost benefit analysis, even when hidden costs are accounted for. We consider here three possible causes for this discrepancy:

[1] Building a Low Carbon Economy; the UK's contribution to tackling climate change.

- an inaccurate understanding of the number of people coming forward each year to consider the financial case for energy efficiency measures;
- an inaccurate representation of the true costs of the technology for the consumer in the market place today (i.e. poorly estimating hidden costs) and:
- a poor representation of the willingness of a consumer group to pay for an efficiency measure and lack of account for laggards in the population.

Our approach can be simply described by the following diagrams:



In the diagram we have given an example of solid wall insulation applied to a dwelling. Data in green boxes is taken from existing CCC work, while data in the orange boxes has been complied in the current work. As the calculation proceeds from left to right, the realistic technical potential is gradually restricted by a combination of demand side and supply side barriers, resulting in an estimate of the annual uptake of the technology.

The first step is the estimation of the number of decision makers per year. For households, the decision to purchase energy efficient technology is either mandatory (when a boiler fails) or discretionary (to install cavity wall insulation). In neither case would such measures be considered annually – they are much less frequent. Similarly, for most businesses, energy costs are a small proportion of overall costs and energy efficiency measures are a low priority.

For certain technologies and situations (e.g. boiler replacement at the end of lifetime), the number of decision makers can be easily estimated and is roughly equivalent to the number of replacement sales each year. Discretionary technologies (such as loft insulation measures), however, require an evidence based estimate of the number of people considering the measure(s) each year.

Once we have defined the subgroup actively considering adopting energy efficiency measures, a simple payback calculation is used to determine the rate of uptake of the technology by the decision-maker group. There is a significant evidence base on consumer willingness to pay (WTP) which shows that a technology with a very quick simple payback will have a greater rate of uptake than a technology which has a longer payback. Simple payback is used as it is easier for householders to understand than a (more accurate) net present value (NPV) calculation. Simple payback is often used by suppliers marketing measures to consumers. This approach was also taken for non-domestic decision-makers where energy is not the core business.

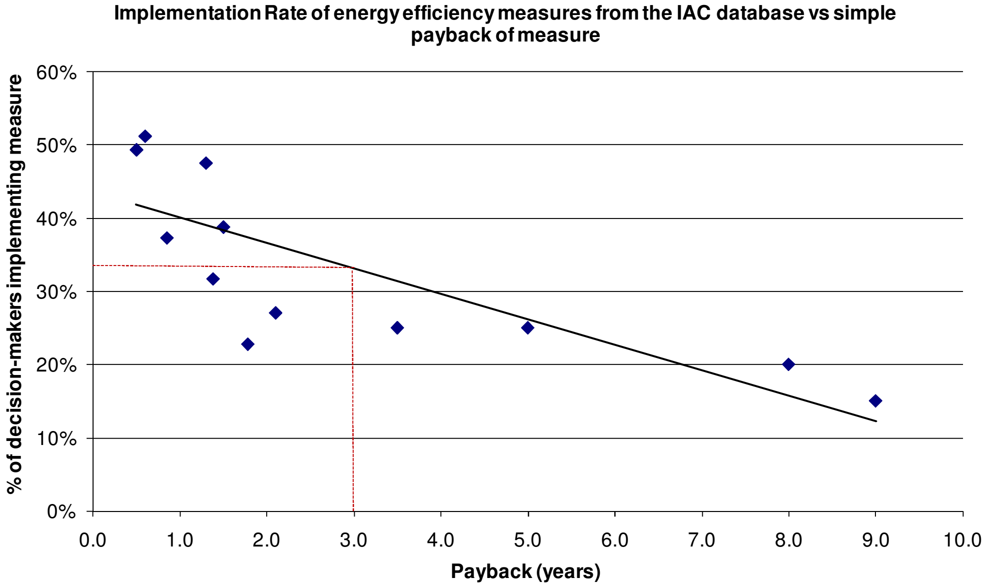
For the payback calculation, the apparent cost of each measure comprises:

- capital cost,
- a cost of time for project/technology identification and appraisal,
- additional engineering costs (e.g. installation costs such as scaffolding),
- a disruption cost (e.g. assigning a value to the time required by the consumer to stay at home to supervise installation, or for time taken to clear a loft)[2].

[2] There was insufficient evidence to include a value for the loss of utility of e.g. space as a result of loft or internal solid wall insulation.

The capital cost of each measure was provided by CCC, but was subjected to a consultation process involving suppliers, Government, and trade associations. The overall cost is then divided by the predicted fuel savings (£) per year to give a payback period.

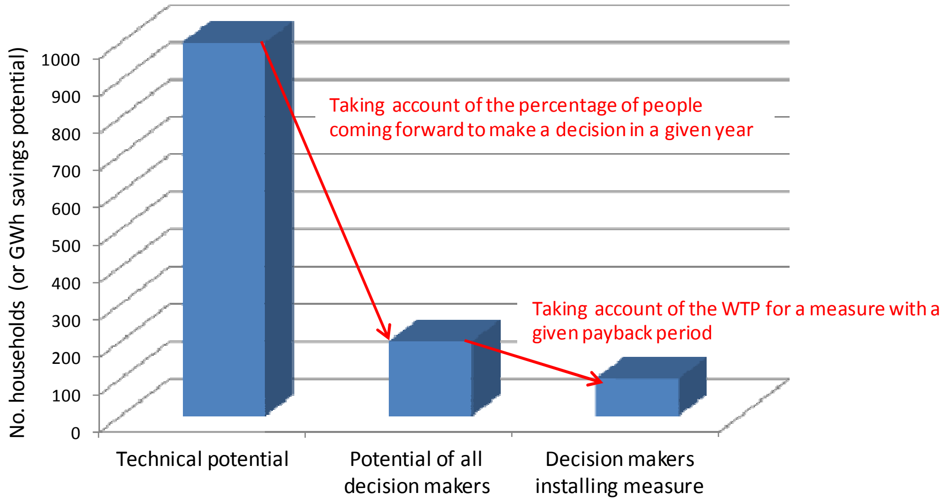
The relationship between payback period and uptake is defined for each of the domestic, commercial and industrial sectors and is based upon the available evidence. For illustration, the following graph is from the Industrial Assessment Center (U.S. Department of Energy) and plots payback period against the percentage of decision makers who implement the measure. A line of best fit is shown. For example, a payback of 3 years yields an implementation rate of about 34% (i.e. approximately 1/3rd of "considerers" become "adopters".



In our analysis the WTP has been expanded to:

- Differentiate between early adopters and laggards – early adopters are much more tolerant to high cost, while laggards may be very slow to uptake the technology
- Respond to the magnitude of the apparent capital cost – data shows that higher capital cost is a barrier to technology adoption, even if payback periods are short.

Using this methodology, uptake of a technology can be increased by increasing the number of decision makers in any given year, decreasing payback time, decreasing the magnitude of the capital cost or switching user types (e.g. from a private landlord to a registered social landlord, with different obligations to tenants and a longer term perspective on energy efficiency measures). The overall process is shown graphically below.



Note that for a small number of technologies (energy efficient lighting and cold and wet appliances), the predicted uptake rate differed significantly from historical observation. In these cases, a calibration with historic data (installation rates observed under EEC1 and EEC2) is applied. The technologies affected were those where there is evidence of non-financial issues taking precedence in decision making (such as the widespread view that low energy light bulbs do not offer the same level of energy service as the incumbent).

Part 1: DOMESTIC SECTOR

This study considers a range of energy efficiency measures and technologies, as shown in table 1, in line with previous modelling work by the CCC (except where stated). Uptake is predicted over the period to 2022. Historic data is also presented, to demonstrate current trends for each measure. We in turn examine the current state of the market, the decision-making process for the installation of these measures and the barriers to their installation. We compare the predicted uptake rates to the CCC reference scenario. Finally, we examine the potential influence of current and future policy or actions to improve uptake.

Table 1 – Full list of technologies and measures[3]

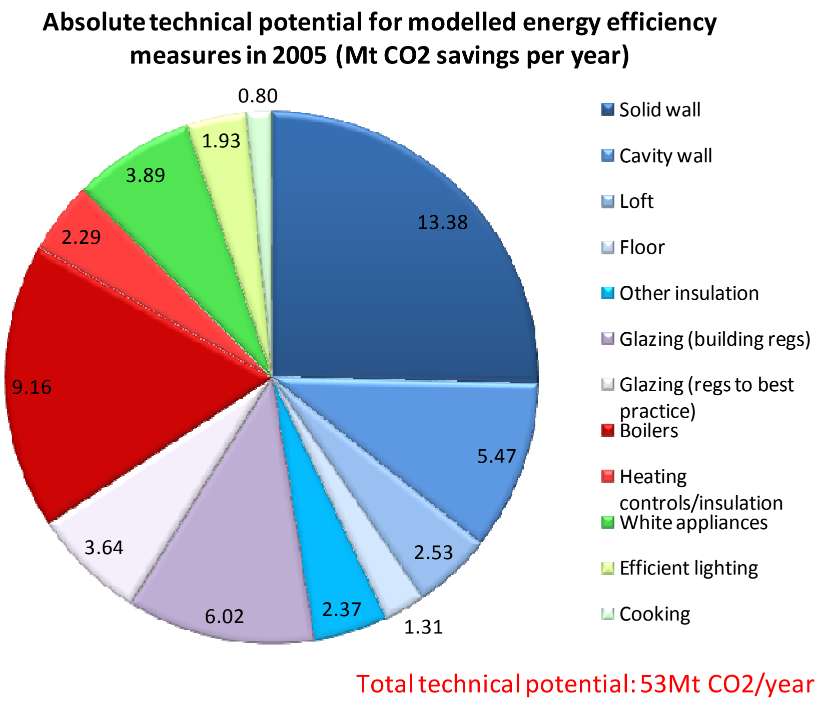
Domestic measures	
Insulation	Cavity wall insulation (pre 76, 76-83, post 1983)
	Solid wall insulation (external, internal)
	Loft insulation (from 0, 25, 50, 75, 100, 125, 150 mm to 270mm), (DIY/installed)
	Floor insulation (susp. timber floors (DIY/installed))
	Glazing - (single to part L building regulations, old double to part L regulations, part L to best practice)
	Insulated doors
	Improve airtightness
Heating	A-rated condensing boiler
	Room thermostat to control heating
	Thermostatic radiator valves
	Hot water cylinder thermostat
	Cylinder insulation (uninsulated, modestly insulated to high performance)
	Insulate primary pipework
Appliances/lights	A++ rated cold appliances
	A+ rated wet appliances
	Efficient lighting
	Integrated digital TVs
	ICT products
	A rated ovens
	Induction hobs
Behavioural	Reduce household heating by 1 C
	Turn unneccesary lighting off
	Reduce heating for washing machines
	Reduced standby consumption

1 STATE OF THE MARKET/ EXISTING DATA

The absolute technical potential for the listed energy efficiency measures is taken from previous work by the CCC. The following pie chart shows the disaggregation of this potential by technology type in 2005.

The technical potential for insulation measures dominates the domestic sector, forming c.60% of the total with solid wall, glazing and cavity wall insulation representing the bulk of the savings.

[3] The following alterations were made to the list of measures: solid wall insulation has been subdivided into external and internal measures, glazing has been re-labelled for clarity where 2006 part L building regulation is equivalent to the previous 'new double' and best practice replaces 'future double' (U-values 2.0 and 1.2 respectively) and finally DIY loft insulation was added.



The following table identifies the remaining homes (in millions) in 2005 that need to be accessed to achieve this potential. These numbers were originally provided by the BRE work for CCC and were verified by Element through analysis of the English House Condition Survey data.

These figures were reviewed during the consultation process. In particular, the association of controls manufacturers (TACMA) expressed concern that the number of homes without basic heating controls is underestimated and, as a consequence, so are the potential CO2 savings. They estimated the technical potential for thermostatic radiator valves (TRVs) and room thermostats in 2006 to be 0.3 and 4.5 MtCO2 per annum respectively compared to the c.2.3 MtCO2 total for controls and insulation listed above.[4] Due to consistency issues with previous work by CCC we have not revised the remaining potential for the reference case, however, once work by TACMA has been completed the CCC may wish to re-examine these figures.

[4] TACMA are currently working with EST to revise the controls estimates based on EST's Home Energy Check questionnaires. They estimated that in 2006, 8.5 million homes had no room thermostat, 13.4 million homes were without thermostatic radiator valves and 1.2 million homes were without any form of control. These numbers are significantly higher than the potentials assumed above.

	TECHNOLOGY	Remaining homes (2005)		TECHNOLOGY	Remaining homes (2005)
Insulation	Pre76 cavity wall insulation	8.32	Heating	A-rated condensing boiler	18.41
	76-83 cavity wall insulation	1.10		Room thermostat to control heating	2.18
	Post '83 cavity wall insulation	1.06		Thermostatic radiator valves	11.84
	Solid wall insulation	7.71		Hot water cylinder 'stat	5.98
	Solid wall insulation (internal)			Uninsulated cylinder to high performanc	1.57
	Loft insulation 0 - 270mm	1.57		Modestly insulated cyl to high performa	4.98
	Loft insulation 25 - 270mm	0.24		Insulate primary pipework	13.72
	Loft insulation 50 - 270mm	1.48	Appliances	A++ rated cold appliances	25.00
	Loft insulation 75 - 270mm	3.84		A+ rated wet appliances	24.95
	Loft insulation 100 - 270mm	5.90		Efficient lighting	22.62
	Loft insulation 125 - 270mm	2.55		Integrated digital TVs	25.00
	Loft insulation 150 - 270mm	4.27		A rated ovens	12.65
	DIY loft insulation			Induction hobs	11.79
	DIY floor insulation (susp. timber floors)	6.00	Behaviour	Reduce household heating by 1 C	20.25
	Installed floor insulation (susp.TFs)	6.00		Turn unneccesary lighting off	18.5
	Insulated doors	7.89		Reduce heating for washing machines	22.25
	Improve airtightness	15.77		Reduced standby consumption	25.00
	Single glazing to part L (2006) double	25.00			
	Glazing - old double to part L (2006) double	7.89			

2005 to present

There has been significant uptake of energy efficiency measures since 2005, primarily as a consequence of the supplier energy efficiency obligation, the Market Transformation Programme and Part L Building Regulations. Historical installation rates under Energy Efficiency Commitment (EEC) 1 (2002-2005) and EEC2 (2005-2008) were ascertained from evaluation reports. These figures can be found by technology later in the report.

Subsidy levels offered under EEC2 have been significant (e.g. 60% capital subsidy for cavity wall insulation) with a considerable increase between non-priority group and priority group customers. Subsidies under the Carbon Emission Reduction Target (CERT) are anticipated[5] to be even more generous over the period to 2011, and the subsidy group has been significantly expanded to include households containing over 70's.

Our interpretation of CERT is that suppliers will need to carry out promotions and offer the subsidy levels required to meet their targets prior to 2011 and therefore this information is key to understanding both historical and future uptake.

1.1 Technology costs

Apparent technology costs were provided to the CCC by BRE/AEA as part of their work for CCC on the MACC curves. These costs were compared with cost estimates in the CERT illustrative mix and an ERA[6] study. In addition seven solid wall suppliers have been contacted by Element Energy. The value quoted here is an average of quotations received and assumes a representative property size of 80m^2, approximately equivalent to a 3 bedroom semi-detached house.

Hidden and missing costs were calculated in this previous work from analysis by Enviros (2006)[7]. This attempt to quantify costs in terms of project identification/appraisal additional engineering and disruption, was not dependent on the specific technology but only its classification into an engineering, non-engineering or behavioural measure. An attempt has been made here to identify technology

[5] The level of subsidy is likely to vary significantly over the period as suppliers aim to reach their targets and compete with each other to achieve the lowest cost solutions to meet such targets. It is therefore difficult to assess the subsidy level over the period with the limited information published from the first 3 quarters

[6] Impact Assessment of EEC2 on the UK Insulation Sector, Energy Retail Association (2004)

[7] Review and development of carbon dioxide abatement curves for available technologies as part of the Energy Efficiency Innovation Review, Enviros (2006)

specific costs, through internal and external consultation and discussions with Ecofys and the Department of Energy and Climate Change (DECC) with reference to their hidden and missing cost project[8]. The time estimates quoted here most closely equate to the lower estimate in the latter work. A literature review did not uncover further evidence for hidden and missing cost estimates by technology in the UK.

1.1.1 Cost of time

The cost of time for domestic consumers was taken as £4.88/hr. This is based on the Department for Transport resource cost for non-work time adjusted to the 2008 value using the Treasury's GDP Deflator. The cost of time used to calculate this hidden cost may also be viewed as an underestimate by some consumer groups (e.g. larger private landlords) for whom the cost of time may be more accurately represented by the resource cost for work time.

1.1.2 Insulation

Cavity wall and loft insulation

Cavity wall and loft insulation represent low-moderate cost technologies (capital cost below £500), which have historically received significant support under the supplier obligation. The following table demonstrates the collated information for cavity wall and loft insulation measures:

Measure	Calculated Simple payback (years), inc. hidden costs	BRE apparent capital cost	Consultation capital cost	Hidden costs (hrs)	Hidden costs (£)	Subsidy required to achieve 3 yr payback	EEC 2 subsidy
Cavity wall insulation (pre 76, 76-83 and post 1983 homes)	3.75, 7 and 12 years	£350	£380	4.5	£22	20%, 57% and 76%	60% (NPG), 93% (PG[9])
Loft insulation (<100mm)	3.15 – 7 years dependent on starting depth	£250-£200 dependent on starting depth	£286	13.5	£66		65% virgin, 50% top up (NPG) 93% and 80% (PG)
DIY loft insulation	3.5 years	NOT CONSIDERED	£120	15	£73		30%

Payback periods for cavity wall and loft insulation are highly dependent on the state of the property they are being installed in and can approach 3 years in some homes, even without a subsidy.

Hidden time values are much more significant for loft insulation with time to clear and refill a loft increasing the hidden costs. This becomes a significant fraction of the overall capital cost for DIY installations or when a large capital subsidy is offered.

It should also be noted that loft insulation of significant thickness may decrease the utility of the loft. The loss of utility is not included in this analysis.

Solid wall insulation

Solid wall insulation (SWI) has a high capital cost and a high hassle factor and has not thus far achieved significant market penetration. In this study it was considered necessary to separate external and internal solid wall installations, due to their differences in cost, hassle, and installation.

[8] The hidden costs and benefits of domestic energy efficiency and carbon saving measures, Ecofys on behalf of DECC, in press

[9] PG = Priority Group. NPG = Non Priority Group

Capital cost differences of greater than £2000 for a three bedroom semi-detached house were quoted by suppliers.

Price estimates were obtained from the consultation process and can be found along with subsidy estimates (both past (EEC2) and future predicted (CERT)) listed in the table below. Costs can vary significantly dependent upon property type, wall area and the number of concurrent installations.

Costs for social housing flats, where the measure is installed in bulk and the finish requirements may be less demanding, can be substantially lower per property. The installation rate in this sector is understandably much higher than for owner-occupiers or private rented properties. In addition, social landlords see the benefits of reduced damp and improved comfort for the occupiers and avoided demolition as an additional driver to solid wall insulation.

Measure	Calculated Simple payback (years) inc. hidden costs	BRE apparent capital cost	Consultation capital cost	Additional engineering costs	Hidden costs (hours)	Value of hidden costs (£)	Subsidy required to achieve 3 year payback	EEC 2 subsidy	CERT estimated subsidy
SWI (external)	27	£4000	6800*	1500	11.5	56	88%	c.15%	47% NPG, 85% PG
SWI (internal)	18		5600	60	21	102	83%	c.15%	46% NPG, 81% PG

The hidden cost (hours) does not include time for redecoration of a property, re-commissioning of electrics, refitting kitchens and bathrooms but does include an allowance for time to empty rooms and allowance for a half day survey.

For external solid wall insulation, any decrease/increase in value due to aesthetic changes in the property are not included in the hidden cost calculation. Additional engineering costs are dominated by the cost for scaffolding.

Glazing

The decision to upgrade windows from single or old double glazing was assumed to be primarily governed by factors other than energy efficiency (i.e. thermal comfort, noise, aesthetics, property value) and the choice of windows with a minimum U-value is mandated under the Part L building regulations. The choice in this study is therefore whether to install the minimum E-rated (or equivalent) windows or a more energy efficient model. The energy savings and apparent capital cost are therefore the differential between the two window types. There are some limited hidden costs for glazing which reflect the time for research to identify best practice installer compared to building regulation glazing. This is chosen to reflect the lack of information currently in the market place. For more details see appendix

Floor insulation

Floor insulation has received little attention to date as an energy efficiency measure, primarily due to the hassle factor involved compared with loft or cavity wall installation. An upper capital cost limit of £800 for a professional installation was suggested by DECC.

For insulated doors and draught proofing see appendix.

1.1.3 Heating

Boilers

The replacement of a boiler at the end of its useful life by an energy efficient equivalent is assumed to be mandated and therefore given an apparent cost of zero. Early replacement of boilers is not considered explicitly in this study.

Controls (heating)

Current building regulations do not require zoning (and therefore the use of thermostatic radiator valves) for a boiler only replacement and therefore are not covered by mandation. Industry was consulted on the costs of heating controls.

According to TACMA a straightforward room thermostat installation could cost £100 but costs escalate when changes to the existing pipework are required. Apparent costs for controls modelled here range from £150 to £250 per installation.

TACMA also noted that the SAP calculation methodology, which forms the basis of determining the energy saving benefits of particular measures, has acknowledged limitations in assessing the performance of controls[10]. Although this is recognised, payback periods in this study are based on energy savings calculations by BRE for consistency with previous work, and do not use revised estimates.

Heating controls also have the potential for non-financial comfort benefits which are not considered explicitly here.

For insulated cylinders and pipework see appendix.

1.1.4 Lighting

Domestic energy efficient lighting measures considered here were assumed to be primarily represented by the replacement of General Lighting Service (GLS) tungsten filament lamps, which represent 60% of the current stock, with compact florescent lamps (CFLs). At present CFLs represent nearly 5% of the lamp sales and 10% of the lamp stock. Strong support for CFLs under EEC and CERT has also meant the delivery of vast numbers of bulbs, free of charge to households, however, the rate of implementation of this technology does not necessarily match this delivered figure. A report by Eoin Lees Energy[11] on EEC2 found more than a factor of six difference between the number of installations reported by energy suppliers and those reported by households during the EEC2 period.

The average price for a CFL bulb is c. £3, compared with 50p for average tungsten filament bulb (ignoring supplier obligation subsidies). This cost differential results in a payback of c.2 years.

According to the latest EU Commission information[12] anti-dumping excise duties which have historically been imposed on CFLs from China are scheduled to end by the time Part II of General Lighting Implementation Measure is in place. This legislation has been in place since 2002 and can represent up to 66% of the cost of the CFL bulb[13]. 99% of CFLs are currently imported from Asia and therefore costs may reduce substantially in coming years.

The choice for consumers, however, is set to drastically reduce as UK retailers and energy suppliers lead a voluntary phase out of GLS lamps by 2011 where there is a suitable replacement alternative.

Halogen lamps are also becoming increasingly important and the decrease in technical potential for CFLs as a result of this growing trend should also be considered. LEDs represent the assumed energy efficient replacement for halogen lamps and represent a long term solution for domestic lighting, however, it is recognised that it is likely that it will be several years before LEDs can compete in terms of general energy efficient internal illumination[14] and cost.

Appliances

The cost differential and associated energy savings between an A++ rated cold appliance and the A rated equivalent, (and similarly between A+ and A rated wet appliances) was provided by BRE.
Market penetration of these higher rated products was determined from the Market Transformation Programme.

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[10] BNDH19, evaluation of heating controls, Market Transformation Programme 2008
[11] "Evaluation of the Energy Efficiency Commitment 2005-08" for DECC, Eoin Lees Energy, 2008
[12] *ec.europa.eu/energy/demand/legislation/doc/2008_03_28_minutes.pdf*
[13] MTP
[14] Policy Brief: Improving the energy performance of domestic lighting products, Market Transformation Programme

2 DOMESTIC DECISION MAKERS

2.1 User breakdown

In this study, domestic decision makers have been disaggregated into the following types: owner-occupier, private landlord, registered social landlord/local authority. Each category has different motivational drivers, practical constraints and barriers and can be targeted through distinct policies. Data from the House Condition Surveys has been used to disaggregate the potential market by user type.

For simplicity, the modelling approach assumes that the decision making in the domestic sector is carried out by the household or landlord. It is recognised, however, that other stakeholders can have a significant influence on the decision-making process, or even the presence of a decision in the outset. Key stakeholders, for example, can include the retailer in the appliances sector, who chooses how to stock, display and advertise his products. Installers and heating engineers also have their role to play, who may recommend (or otherwise) products such as controls or additional insulation. In addition, certain measures such as adequate controls are a prerequisite to behavioural change decisions. Further analysis of this interaction is considered beyond the remit of this study.

2.2 Replacement/non-discretionary technologies

The following technologies were identified as replacement or non-discretionary measures, i.e. purchase decisions are normally made when the incumbent technology reaches the end of its useful life. The maximum constraint on uptake for these technologies is typically dependent on the life of its predecessor. Where information was available, historical annual sales were used to define the decision making frequency and supply chain constraints.

In addition, internal solid wall insulation was defined as having a fixed decision making frequency of no greater than 8% per annum. The degree of hassle and additional engineering costs involved with stripping out kitchens, bathrooms, removing radiators, and redecorating were deemed too great to allow installation except when renovation or redecoration is already being carried out. This rate was therefore set as 8%, roughly the frequency of occupancy change in the residential sector.

Technologies: Appliances, lighting, boilers, internal solid wall insulation, glazing

2.3 Discretionary technologies

A study by Oxera[15] suggests a decision making time-scale of 12.5 years (i.e. a yearly decision making frequency of 8%) as a baseline for energy efficiency measures affecting the fabric of a house (e.g. cavity wall insulation). This value has been used to model campaigns to increase consumer awareness of technologies and is similar to the average occupancy of a property. Previous work by Element Energy set this domestic decision making frequency at 7%[16] following a review of consumer surveys.

Ongoing work for the Energy Saving Trust (EST) suggests home renovation and extension represents an important opportunity with 20% of homeowners having installed an energy measure at this trigger point and 32% suggesting it would motivate them to do so.

Data from EEC 1 and 2 has been used to check the number of decision makers for discretionary technologies. This decision making frequency of 8% per annum was sufficient to predict uptake of insulation measures under the observed subsidy levels for the priority and non-priority groups[17] in the

[15] Policies for energy efficiency in the UK household sector, Oxera, 2006

[16] BERR Microgeneration Study, Element Energy,

[17] The supplier obligation requires a certain percentage of action to be taken within a so-called priority group. The priority group was historically defined as households in receipt of one or more of a list of benefits under EEC2. It has now been expanded under CERT to include households over 70.

earlier phases of EEC. We predict that marketing efforts in CERT are likely to drive up the decision-making frequency during this period.

A higher rate of decision making was used for registered social landlords (RSLs)/local authorities and landlords. This is decision frequency is set at 14% in the reference scenario. The structure of the Supplier Obligation to require a certain percentage of action to be taken within a Priority Group has led to RSLs and their tenants receiving more aggressive targeting and more generous support. The decision-making frequency is chosen to reflect this. It is also assumed that private landlords may see a higher rate of decision-making, reflecting the frequency of their tenant changes.

Technologies: Cavity and loft insulation, external solid wall insulation, floor insulation, heating controls, other insulation measures

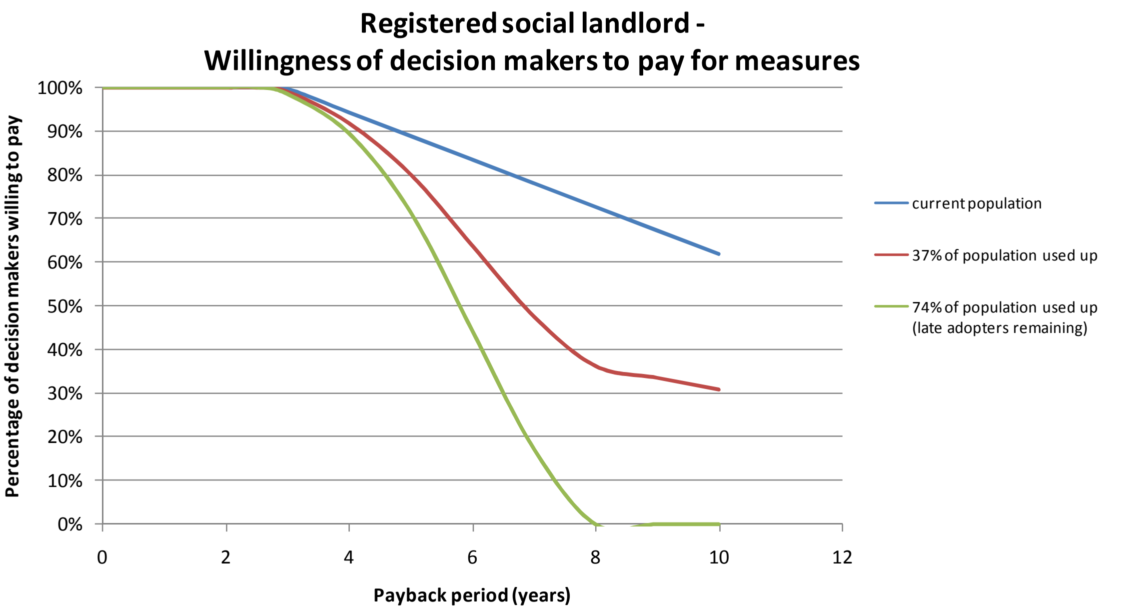
3 WILLINGNESS TO PAY

A percentage of decision makers can be predicted to adopt a given measure based on the simple payback period they anticipate. In this study we have separated consumers into owner-occupiers, social landlords and local authorities and private landlords and each group can be observed to have different willingness to pay curves. These graphs and those found subsequently have been derived from the following sources of information:

- Consumer surveys undertaken as part of projects undertaken for the Department of Business Enterprise and Regulatory Reform (BERR)[18]
- The Department for Environment, Food and Rural Affairs (Defra) household survey data
- Landlords quantitative research carried out by the Energy Savings Trust (EST)[19]

The number of decision makers willing to pay for a measure is also dependent on several other factors including the composition of the population at the time (i.e. their overall attitude to energy efficiency measures and willingness to act irrespective of payback), and the absolute magnitude of the costs involved.

3.1 Registered Social Landlords/ Local Authorities



This example shows the willingness to pay of registered social landlords (RSLs) considering energy saving measures. The blue line represents the behaviour of the overall population of RSLs. This is representative of technologies that have achieved limited uptake – those adopting the technology will have a greater WTP than the mass market, or laggards. With the current population, c.60% of RSLs considering the measure are willing to pay for a measure with a payback of 9 years. As measures are adopted and the remaining population becomes smaller, laggards begin to dominate. The required payback time to achieve this rate of uptake shortens dramatically. The green line represents the payback requirements for the last 26% of RSLs.

RSLs and local authorities can be expected to benefit from economies of scale by:

- Reduced financial costs of measure from bulk purchase, and reduced installation cost
- Reduced time cost per dwelling
- Relationships with known contractors

[18] The growth potential for Microgeneration in England, Wales and Scotland, BERR (2008)
[19] Landlords Quantitative Research, EST and Continental Research (2005)

In addition they are likely to benefit from improved property condition which reduces fuel poverty of their tenants and reduces damp, improving the quality of life and fulfilling duties to their tenants. They may also benefit from avoided demolition costs if substantial refurbishment is undertaken. Social housing providers traditionally view investments in energy efficiency over longer timescales than their private sector or owner-occupier counterparts.

3.2 Private landlords

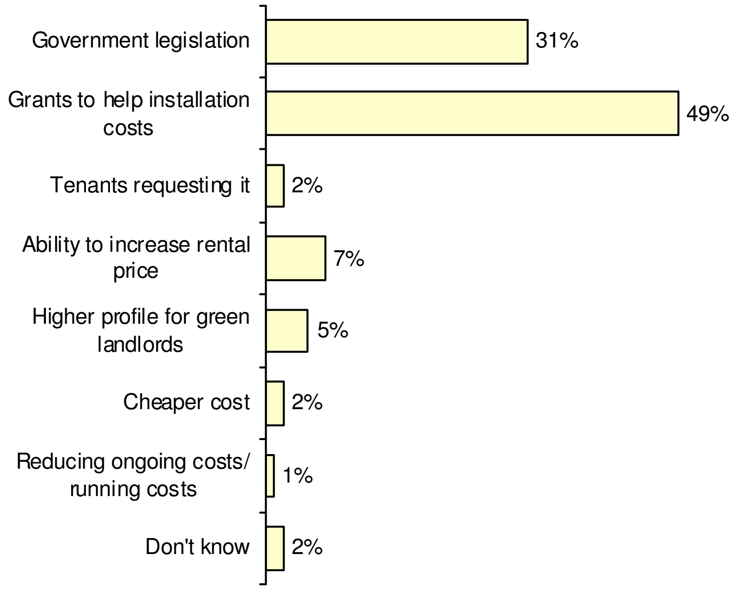
Private landlords represent the other extreme in this study. Work by the EST identified a significant increase in spontaneous identification of the following reasons for not considering energy efficiency measures in landlords leased property compared with their own homes:

- Don't think it is necessary
- Minimal cost savings
- It's not my responsibility (i.e. up to the tenants)

They were also more likely to feel their property reached the required standards and that this was sufficient.

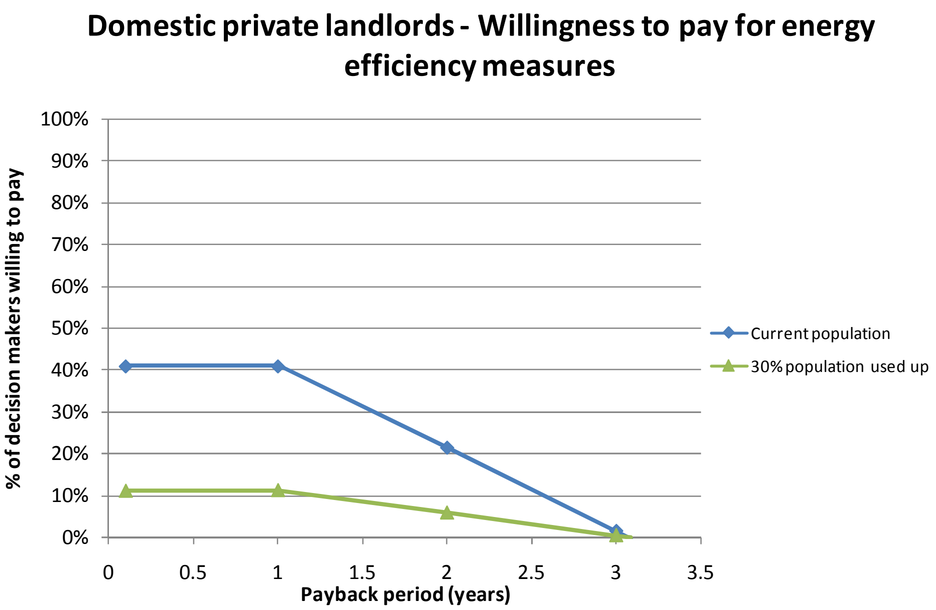
59% of domestic buy to let landlords agreed with the statement that tenants were not bothered as to whether the properties they rent are energy efficient and 34% agreed strongly with this point. These survey results were used to define the number of laggards in the private landlord population. On the other end of the scale only 20% of landlords agreed strongly that they consider how energy efficient a property is at the point of purchase.

Most likely factor influencing decision to install energy efficiency measures in rented properties



Source: Landlords Quantitative Research, Continental Research on behalf of EST (2005)

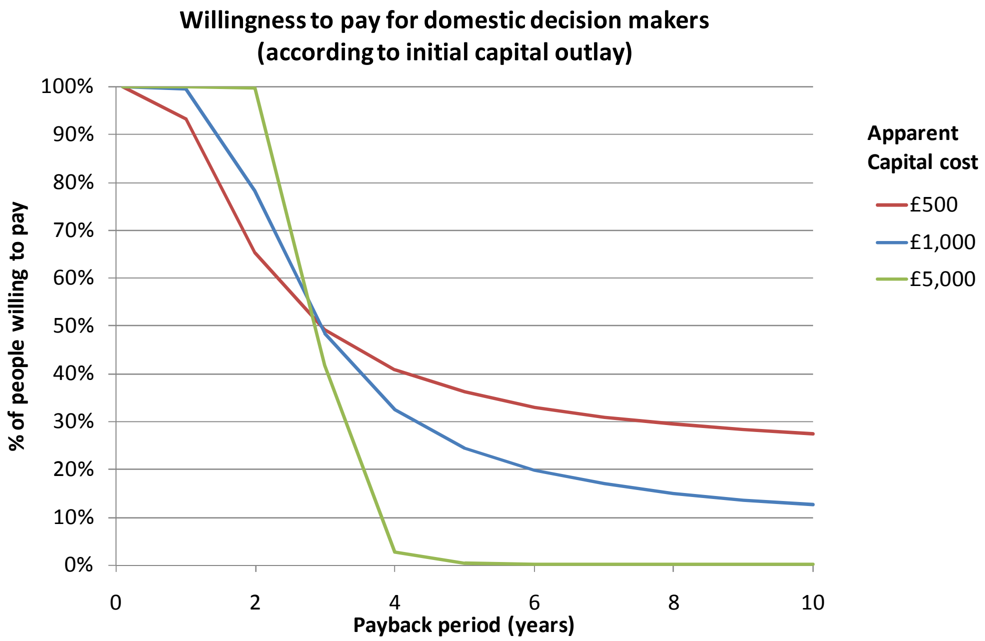
We assume landlords who think higher rental rates may be forthcoming will pay for a measure if payback is less than 1 year. These decision-makers may also be able to persuade the tenant to pay for part or all of the measure to reduce the cost. We also assume that no landlord will pay for measures with paybacks of longer than 3 years. Laggards, representing 59% of population expect no rental increase or resale value increase and therefore receive no payback and no uptake. In the graph below, the green line therefore represents an intermediate population between these two end groups.



3.3 Owner-occupiers

Owner-occupiers represent the largest segment of the population as c.71% of householders in the stock as a whole. As part of a study on microgeneration technologies Element Energy determined coefficients linking capital outlay and ongoing savings to a householder's willingness to pay based on the survey data. These coefficients have been used to create an equation which describes the curves shown in this section.

The shape and gradient of the curves is dependent upon the magnitude of the initial apparent capital outlay. A rapid drop off as simple payback periods increase beyond 2-3 years is, however, observed in all cases.



Ongoing work by Element Energy with the EST found the following response to a survey question, "What stopped you from installing energy saving measures in your home?"

What stopped you from installing energy saving measures in your home?	
Purchase cost	57%
Not got round to it	21%
Payback too slow/ saving too small	21%
Lack of knowledge about how it works	15%
Hassle	13%
Don't know where to get information/installer	11%
Time required	7%
I live in a conservation area/listed building/need planning permission/ have lease restrictions	6%
House not suitable	6%
Other	10%

Purchase cost is clearly a key concern for householders, hence its inclusion as a main factor in this analysis. The hassle barrier was noted to vary by technology, being significantly higher for loft insulation and internal wall insulation (25%) compared to cavity wall insulation 12%.

Laggards

As with other user-types, willingness to pay decreases as the population is used up and laggards begin to dominate the remaining population. In the case of owner-occupiers, for example, a £500 measure with a 2 year payback achieves no uptake in the laggard group, but would achieve a c.65% implementation rate in the starting population as a whole.

The percentage of laggards present in the population was defined by examining evidence from Defra's survey of attitudes, knowledge and behaviour in relation to the environment and Defra's segmentation model. This is a key variable in the modelling approach and is set at 28% of the reference population.

Defra's survey of attitudes, knowledge and behaviour in relation to the environment		
Behavioural	Agree with statement – I always/very often leave TV on standby overnight	18%
	Agree with statement – I would not sacrifice my home comforts to save energy	26%
	Agree with statement – I don't really give much thought to saving energy in my home	24%
	Either not willing, or not engaged, or have tried and given up in reducing gas/electricity at home	21%
Appliances	Disagree with statement – If I was buying a kitchen appliance like a freezer or oven, I would only choose one with a high energy efficiency rating, even if it cost more	18%
	Disagree with statement – I would be prepared to pay more for environmentally-friendly products	29%
Defra estimates (segmentation annex)		
Insulation	Would not be willing to install insulation	35% (does not consider their ability to act)
Behavioural	Would not be willing to carry out energy management measures	20% (assumes no barriers such as cost, inclusion)

Research carried out by the European Efficient Residential Lighting Initiative[20] also suggests that 30% of European households do not want to have CFLs in their home.

[20] http://www.managenergy.net/download/nr295.pdf

Ongoing work for EST suggests that people who would not take up an energy saving measure are most likely to show the following traits:

- A lack of interest in energy saving and climate
- Plan to stay for a shorter time at their current home OR have owned their homes for over 10 years
- Less educated/ low social grade

Loans

Based on ongoing work with EST, homeowners appear to look unfavourably on loans with payback periods of over 5 years. This is primarily for psychological reasons surrounding debt, and also for a lack of certainty in length of time they plan to stay in their house. Low interest loans from governments or energy suppliers were also viewed more favourably than the equivalent from a bank, reflecting the current distrust in the banking sector.

3.4 Increasing uptake of a technology

Using the above methodology, the uptake of a technology can be increased by:

- increasing the number of decision makers in any given year,
- decreasing payback time,
- decreasing the magnitude of the capital cost
- switching user types (e.g. from a private landlord to a registered social landlord, with different obligations to tenants and a longer term perspective on energy efficiency measures).

The approach to intervention in the market will be based on one or more of these routes. For example, increasing the number of decision makers may be achieved through an effective marketing campaign.

4 DEMAND-SIDE BARRIERS

In this section we show how demand-side barriers, which limit the uptake of new technologies, are represented in the model. Demand-side barriers to uptake and the appropriate operation of energy efficiency measures occur at each stage of the production cycle, from the initial inception, through the specification, design, installation, commissioning and handover. We have attempted to design an approach which will take many of these barriers into account and allow analysis of their impact on the uptake of given technologies.

There have been many previous attempts to classify these issues at a strategic level. This work attempts to build upon work carried to date, in particular classifications of barriers and hidden and missing costs by Nera[21], Enviros[22] and the Carbon Trust.

THIS REPORT	NERA (2007)	ENVIROS (2006)	CARBON TRUST (2005)
Information	Lack of information		Behaviour/Motivation
Inertia	Psychological/social barriers		
Financial barriers	Financial barriers		Financial cost/benefit
Split incentives	Split incentives		Market misalignment
	Regulatory barriers		
Project identification, appraisal and commissioning	Hidden costs	Project identification	Expanded cost/benefit
		Project appraisal	
		Project commissioning	
Disruption		Production disruption	
Additional engineering		Additional engineering	
	Risks and uncertainty	Perceived risks	
Quality of Commissioning/ handover			Quality of Commissioning/ handover
Ongoing management time		Ongoing management time	Ongoing management time

Enviros's five categories of "missing" costs, linked to the production cycle (project identification, appraisal, commissioning, production disruption and additional engineering) were considered in the CCC's previous analysis.

There has been less focus to date on considering the applicability of the barriers to a particular technology or end-user type. When considering realistic future uptake rates and potential opportunities for increasing deployment through targeted policies, we consider technology specific barriers to be of primary importance. Generic hidden/missing costs have been replaced with technology specific values where possible. The applicability of barriers to each user type in the modelling process has also been considered.

4.1 Quantification/ modelling of demand barriers

The following diagram explains how barriers are represented in the model. Broadly speaking barriers may:

- Reduce the number of people coming forward in a given year
- Add a hidden cost such as the cost of time to a project
- Reduce the ongoing cost savings of a measure
- Change the behaviour of the decision-maker and hence their willingness to pay (e.g. moving from owner –occupier to landlord)

[21] Evaluation of Supplier Obligation Policy Options, Nera Consulting (2007)

[22] Review and development of carbon dioxide abatement curves for available technologies as part of the Energy Efficiency Innovation Review, Enviros (2006)

	Barrier	Impact	Model variable
Inertia	Lack of engagement from some consumers	Benefits of energy efficiency measures not considered by large proportions of the population.	% people coming forward to make a decision each year, and % late adopters in each user type
Info.	Inaccurate/lack of knowledge of current energy consumption/ technology costs	Incorrect calculation of payback of measure	% of people coming forward to make a decision each year
Financial	Capital cost/ poor access to finance	High capital costs, decrease willingness to pay for product, even with short payback times	Capital cost £
	Long payback period cf. consumer horizon	Householders typically view payback over a 3 year time horizon, time period is typically even shorter for private tenants	Consumer lifetime of measure (years)
Hidden costs	Time input required for project identification, appraisal and commissioning	Increases hassle to consumer of installing measure	Barrier cost (time) £/hr
	Disruption (e.g. supervision time required for installation)	Inconvenience to consumer (e.g taking time off work)	Barrier cost (time) £/hr
	Additional engineering required (e.g. scaffolding, redecoration)	Increases overall cost of measure	Barrier cost (engineering) £
	Ongoing management/supervision required	Decreases perceived value of energy savings	Ongoing cost (time) £/hr
Split incentive	Landlord - tenant split incentive	Landlord does not see benefit of energy saving	user type
Commision/ handover	Poor commissioning and/or handover leads to poor operation of system	Reduces energy saving of measure	Factor reducing energy savings per installation
Use	Ongoing management time required	Reduces the net value of energy savings	Ongoing cost (time) £/hr
Loss of utility	Consumers have a perceived loss of utility/ comfort	Loss of utility of, e.g. space for loft and internal SWI	Barrier cost (not included, cost hard to verify)

4.1.1 Poorly aligned/split incentives

Split incentives in the domestic rental sector can be subdivided as follows:

- Financial – The landlord does not see benefit of ongoing cost savings and there is limited scope for increase in rental payment to tenant
- Safety and liability – The landlord's responsibility for safety may prevent e.g. tenants installing DIY loft insulation
- Additional time requirement – Landlords may require additional time to liase with tenants and additional time to research grants due to added the complexity and lack of transparency in this sector

This has been modelled by assuming a much more pessimistic willingness to pay curve for private landlords as previously discussed. It should also be noted that there could also be some hidden benefits for larger buy-to-let landlords (e.g. bulk installation of measures across a property portfolio, existing relationships with potential suppliers). Lack of data means it has not been possible to consider these further.

4.1.2 Commissioning/handover and use

This barrier represents a potential loss of CO_2/energy savings through poor installation and handover to the user. It may also act to discourage the user from installing further measures as prior saving expectations were not realised. Complex control systems, for example, which require detailed instructions and time input from the householder, may lose much of their benefit, particularly in rented accommodation with frequent tenant changes. This cannot be ignored if savings are to materialise.

4.2 Technology specific demand side barriers

The following section presents non-financial or time related barriers to the uptake of technologies.

4.2.1 Lighting

Research carried out by the European Efficient Residential Lighting Initiative[23] suggests that 30% of households do not want to have CFLs in their home. The stated reasons for this are variable and include:

- Practical concerns - Lack of fit to luminaires, plug and play CFLs are not dimmable, noticeable warm-up time
- Aesthetic concerns - Dislike of classic CFL shape, colour temperature, rendering
- Health concerns – e.g. flickering and migraines/epilepsy
- Pollution from low-quality products (e.g. with long warm-up time, poor output) – prevent market penetration, particularly into laggards sector

4.2.2 Insulation

Loft and internal solid wall insulation suffer from a barrier of perceived loss of space. This is frequently mentioned by participants in surveys, though good technology choice can help reduce any impact. The value of this loss of space is very hard to define as it is dependent on a host of variables (e.g. geographic location, size of property).

External wall insulation affects the aesthetics of a property. While the impact can sometimes be positive, depending on location consent from neighbours and planning departments may be required and this may drive up the hassle and time taken to reach installation.

4.2.3 Heating controls

Heating controls are seen as low value work, and there is a current lack of incentive for installers to advise on controls. Barriers to installation of control systems separate to a boiler replacement remain high.

System complexity can even lead to a negative recommendation. Digital controls with multiple functions can be too complex to use without a manual. Boiler installers and maintenance staff will not recommend controls that they cannot operate. Behavioural energy saving potential requires the presence of easy-to-use controls (e.g. reducing temperatures by 1 degree) and therefore the importance of this measure should not be underestimated.

[23] http://www.managenergy.net/download/nr295.pdf

5 SUPPLY CHAIN BARRIERS

In this approach, sales per year are both demand and supply chain constrained and may not exceed either limit.

The following section examines the current supply chain for the range of measures considered and examines the potential for further expansion over the period 2009-2022. Installation rates and sales per year noted under the supplier obligation (2002-present) and in the Market Transformation Programme are used to define historical supply chain limits. The future supply chain envelope has been derived from a literature review of key documents and from consultation with industry. Where assumptions have been made these are stated.

The following generic barriers are recognised as barriers to supply chain expansion and limit sales per year:

- Availability of raw materials
- Ability to scale up production
- Availability of qualified installers
- Restrictions on credit flow in the supply chain
- Owning an appropriate business model
- Ability to identify appropriate customers

The availability of materials and installers has been reviewed on previous occasions (for example in the UK Insulation Sector Supply Chain Review carried out by ESD 2007). Concerns regarding restrictions on credit flow in the supply chain have been a recent development in response to the current recession. It is hard to quantify the impact this may have on expansions of the supply chain, however, it is hoped that positive support from the Government in the 2009 Budget should act to reassure the market.

The ability to identify appropriate customers is a key barrier in this sector. The number of households coming forward in any given year to make a decision on energy efficiency measures is dependent on the degree of media coverage and marketing reaching the targeted audience. The number of decision-makers is a key parameter and is rate-limiting on adoption of measures.

CERT has a requirement for suppliers to meet their targets with 40% of actions from priority groups. Finding those who are classified as a priority group and have not already received help under EEC1 and 2 may prove challenging. These households may also have been heavily targeted during EEC1 & 2, with the remaining population is harder to access. The expansion of priority groups to include households over 70 is likely to counteract this issue, although ongoing work with EST suggests the older population, particularly those who have been in the same property for 10 years or more, present a harder target audience for energy efficiency measures.

5.1.1 Cavity wall insulation

The supply chain envelope is defined in this study by the upper bound from ESD 2007. This limit is constrained by installers out to 2010 and by material constraints in subsequent years[24]. In 2009, a maximum of 1 million installations may be carried out. This increases slightly to 1.25 million installations per annum by the end of the CERT period (2011) and remains constant until the end of the period.

	EEC1	EEC2	CERT
Installation rate (average per annum)	264,000	445,000	967,000

Installers estimated that the cost of a machine purchased in late 2007 could be fully amortised over 4 years at the rate of installations expected under CERT, however, as the market for cavity wall

[24] See appendix

installation becomes saturated, the rate of installations decrease and amortising new equipment will become increasingly difficult. Capital costs for machines require high utilisation to achieve the quoted payback time.

If the rate of installations is accelerated, the number of installers can only be expected to increase if there is sufficient demand remaining to allow the equipment to be amortised. The number of installers in this sector has been estimated to fall from its peak following CERT (initial phase)[25]. Maintaining a suitable distribution of installers will become increasingly difficult as the demand base reduces.

5.1.2 Loft insulation

Shortages of material affected the loft insulation market towards the end of EEC1. This remains the dominant concern for loft insulations where DIY installations are commonplace. Unlike cavity wall insulation, no formal training is required for loft insulation and many installers also carry out cavity wall insulation. Manufacturers have noted that shortages in material are possible towards the end of CERT if there is no further investment in capacity. The Government, however, has been issuing clear signals that deployment of 'easy to treat' measures such as loft insulation should be carried out as far as possible before 2015.

Installations	EEC1	EEC2	CERT
Professional	754,741	1.26 million	2.4 million[26]
DIY	355,097	649,211	600,000

ESD estimated the capacity of the loft insulation market based on the required tonnage of material to be 1.057 million installations per annum over the CERT period.

No. installers (2009)	c.4000[19]
Capacity	1.057 million installations per annum[13]

5.1.3 External SWI

ESD (2007) suggests there is capacity for an increase of 10,000 installations per year in the short term and this limits installations for the next 5 years in the model. INCA has also suggested that the industry now has capacity to insulate between 20,000 and 50,000 one-off homes given a 2-3 year notice period. DECC projects that the market could double in capacity to retrofit insulate 20,000 p.a. under CERT 2008-11.[27]

Beyond 2014 the industry is here allowed to grow at 50% per annum, a strong growth rate, levelling off in 2019/2020. Trade associations have indicated that given the right level of support and clear indication of future policy, c.40% uptake could be achieved by 2022, matching well with the limit of this supply chain envelope. This is an ambitious growth rate and barriers exist to such supply chain expansion including:

- Uncertainty in demand due to historically low uptake rates
- Lack of strong relationships between energy suppliers and SWI industry
- Switching from mainly social housing installations to addressing wider audience

5.1.4 Internal SWI

Internal solid wall insulation appears to have little restriction on ramping up capacity. Material for flexible linings is currently imported from Europe, and ESD suggests that supplies can be increased significantly at short notice. Training for installers (who include decorators and jobbing builders) usually lasts c. 2 days and is often carried out by the insulation supplier.

For rigid thermal boards, there appear to be few constraints on increasing the amount of installations from the supply chain. Internal domestic solid wall insulation is currently a small percentage of the UK

[25] An assessment of the size of the UK household energy efficiency market, Energy Efficiency Partnership for Homes.2008

[26] The Department of Energy and Climate Change (DECC) predictions. DECC's draft illustrative mix for CERT 2008-11 is not prescriptive and does not necessarily reflect the way which suppliers may chose to achieve their targets

[27] The UK Residential Energy Efficiency Market Development MBD 2008

plasterboard market. British Gypsum has indicated that[28] in terms of raw material, capacity can be increased easily. Installations are typically carried out by dry lining contractors or jobbing builders.

Installations	EEC1[29]	EEC2	CERT
Internal SWI	800	35278	100,000
External SWI	23,200		50,000

5.1.5 Floor insulation

Floor insulation has not been a focus of government policy to date. The 2008 market size has been estimated at c. £68m[19]. Information regarding installations surrounding this measure is limited. BRE assumed 100,000 installations per year could occur in their previous analysis for CCC.

5.1.6 Glazing

Predicted window sales in 2009 are 9.15 million units, and secondary glazing 195,000 units, according to Palmer Market Research and sales have been relatively steady since 2002. 67% of windows are estimated to be purchased as home improvement, 16% for new housing and 17% for social housing.

The market for upgrading single to double glazing in the domestic sector appears to be maturing (although not all replacement double glazing has been carried out to current standards). 83% of homes had some form of double glazing by 2004 and market saturation has been identified as a key issue, with a very high percentage of homes in the private sector now fitted with replacement windows.

5.1.7 Boilers

This market is heavily demand constrained as the number of early replacement boilers versus distressed sales is low. The number of yearly boiler sales in 2006 in the UK is taken as 1,576,000[30]. There are an estimated 105,000 installers and operatives of gas boilers in the UK in 2008-9[31].

5.1.8 White goods/ ICT

These sectors are not seen to be constrained by availability of installers. Current and projected sales of goods will be taken from the Market Transformation Programme, with the upper limit of sales coming from their Earliest Best Practice scenario (i.e. all consumers buy one of the most efficient products available at that future time).

5.1.9 Lighting

At present, 99% of UK CFLs are imported from Asia. The market for bulbs is an international one, and any supply side constraints are likely to be global.

The European lighting industry have reported in their comments to the EU's study for the Ecodesign for energy-using appliances, that there could be serious capacity problems with a coordinated and global phase-out of incandescent bulbs. There are current concerns that if the EU, North America and Australia all legislate simultaneously, to implement a sudden phase out traditional incandescent bulbs, CFL production may not meet demand. This view is not shared by all, Greenpeace CFL suppliers do not see an issue with peak demand due to phase out in 2011.

According to the European lighting industry, in 2007, the global demand for GLS is estimated to have been at least six times global CFL capacity, following the sudden upsurge in public interest in CFLs. Investments in new production capacity to keep up with this have been and continue to be made, but even so there is a lag involved that must be recognised in any timetable. It is expected, in the long term, that China will consume the demand for CFLs without a significant influence on its production capacity.

[28] ESD (2007)
[29] Ofgem
[30] UK Domestic Heating Sector 2007, Purple Market Research
[31] An assessment of the size of the UK household energy efficiency market, Energy Efficiency Partnership for Homes (2008)

6 RESULTS

In this section the results of the modelling are presented and discussed. Graphs show the uptake of the remaining 2005 potential, for consistency. In each case data from EEC2 (2005-2008), or for appliances the Market Transformation Programme, was used to define the historical trajectory for this period. Subsidy levels and figures for the number of measures installed in this period were taken from the Ofgem review[32] and the Eoin Lees Evaluation of the Energy Efficiency Commitment 2005-2008.

The modelling begins at the present day (end 2008), but in each case, the number of installations per year in the EEC2 period was predicted and checked against the EEC2 historical data. For insulation measures errors were typically small (see appendix) and calibration was not deemed necessary.

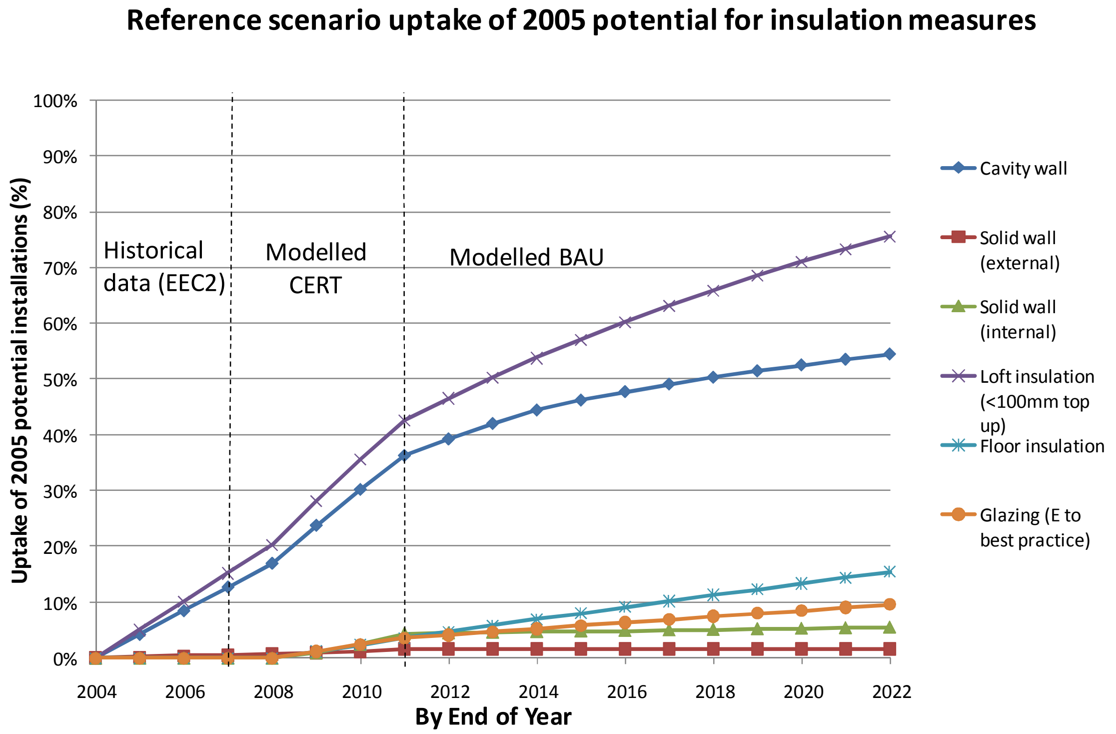
6.1 REFERENCE SCENARIO

The reference case is defined by CCC and only includes policies firmly funded and committed to, prior to the Energy White Paper (2007). It includes, for example, the current phase of CERT (2008-2011) but does not include any post 2011 supplier obligation, despite the Government's current vision to continue this in some form. It also does not include the 20% uplift to the target announced in September 2008, expected to boost supplier household energy efficiency investment by £560m by 2011. Furthermore, the reference scenario does not take into account that the Government has since announced its ambition to achieve all easy-to-treat measures (such as loft insulation and cavity wall insulation) by 2015.

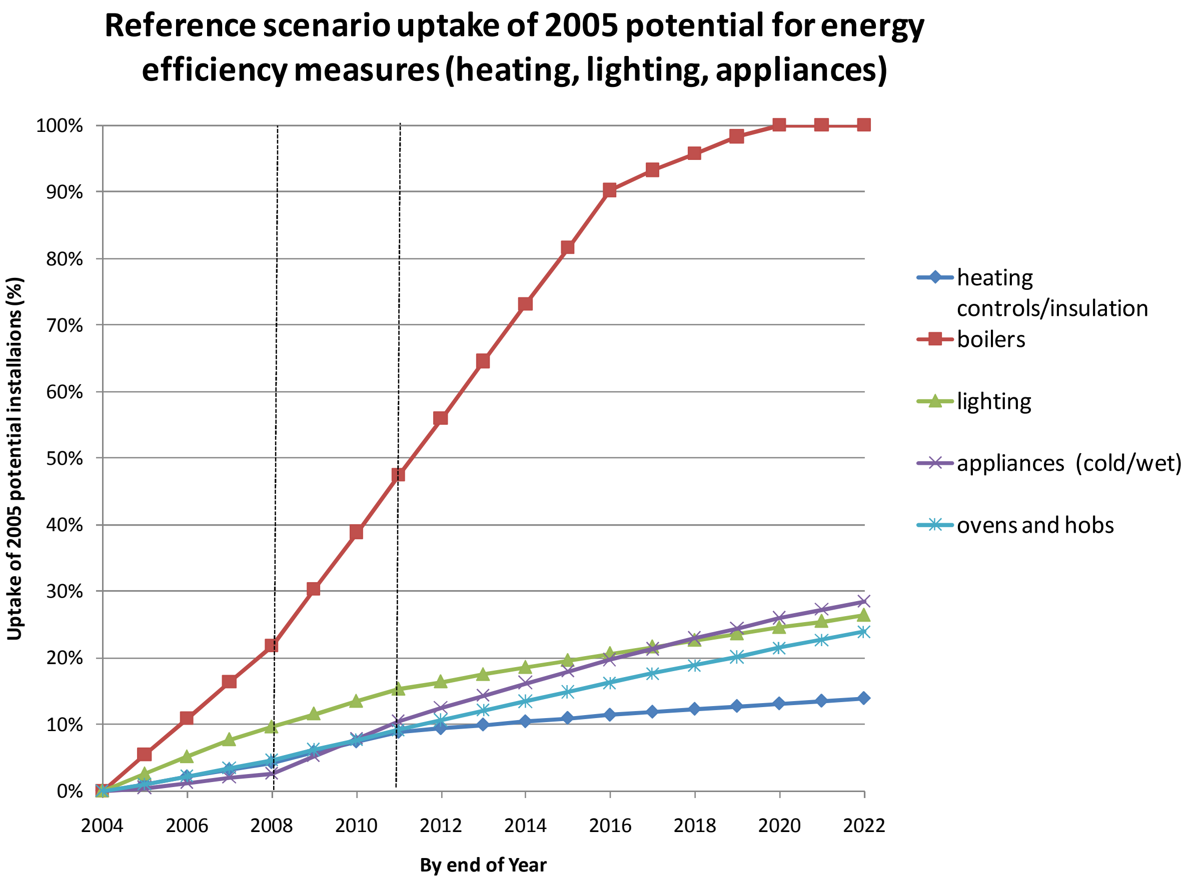
6.1.1 Reference trajectories

By way of example, the following graphs show the predicted reference case uptake for insulation measures and energy efficiency measures. As mentioned above, the trajectory up to 2008 is defined by historical data. The modelled CERT period assumes the maintaining of subsidies to consumers as described in the CERT illustrative mix[33]. Registered social landlord properties are assumed to receive the significantly more generous priority group funding. A considerable proportion of owner-occupiers also receive priority group subsidies due to the expansion of the group to include those aged 70 or over.

[32] A review of the Energy Efficiency Commitment 2005-2008, Ofgem report for Defra, August 2008
[33]. Explanatory Memorandum to the Electricity and Gas (Carbon Emissions Reduction) Order 2008, No. 188



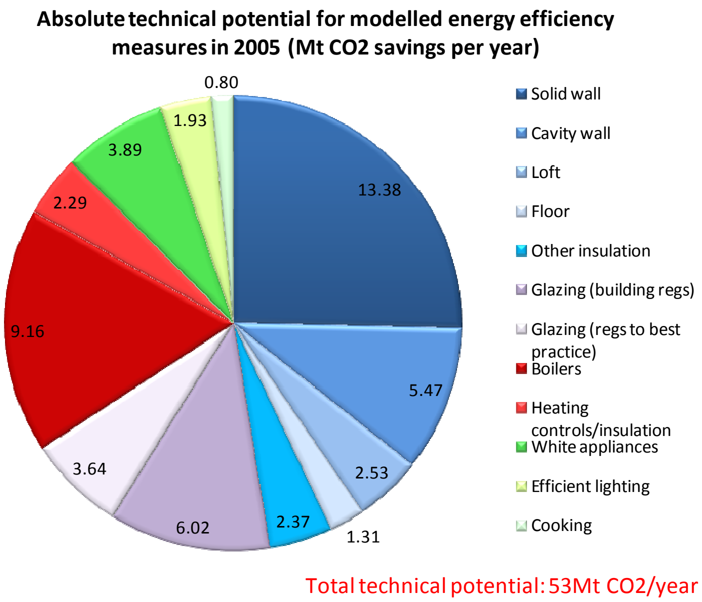
On average, due to a combination of increased ambition (and hence predicted subsidy levels) and the expansion of the priority group, subsidy levels are higher for CERT than for EEC2. As a result payback periods are shorter and even without increasing decision-making frequency, uptake is noticeably higher. After 2011, in the reference case all subsidy is removed and uptake rates once again fall. Floor insulation is assumed to have received no subsidy under CERT and is therefore the only measure to continue its uptake trajectory.



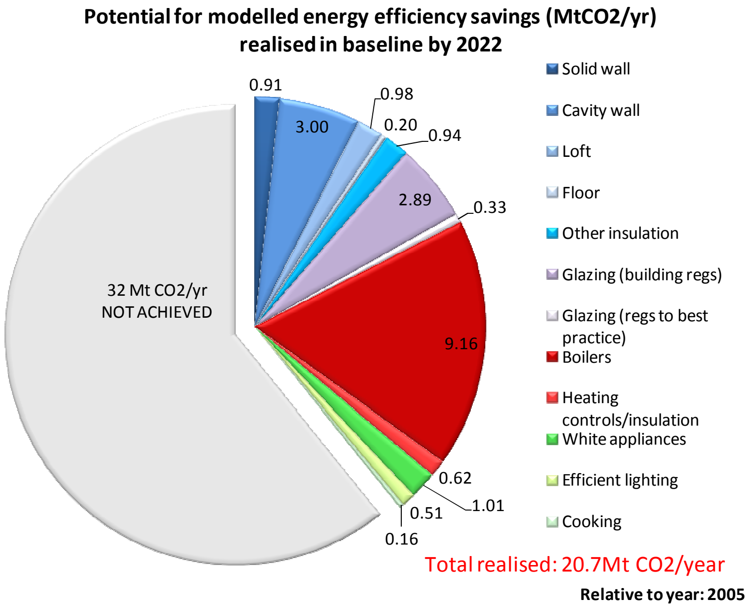
It is important to note that the model calculates uptake for each technology (e.g. different depths of loft insulation) and for end user type. Results are aggregated subsequently to produce the results as above. Variation in uptake between user types is significant and changes in gradient in the resulting aggregated graph, where no policy has been added/removed can often be explained by looking at the underlying user types (for more details see appendix).

6.1.2 Reference case savings versus technical potential

To put these figures in context, the CO_2 savings associated with the business as usual case are best compared with the technical potential of each technology. The pie charts below illustrate the difference between technical potential and achieved uptake by 2022. Approximately 65% of the total technical potential (as measured in CO_2/year) is not achieved under the reference case by 2022. Technologies which are already covered to a large degree by mandation such as boiler replacement and upgrading glazing to building regulation standard achieve a significant proportion of their technical potential and uptake is governed by the replacement rates for the measures, however, there is notable under-performance in other sectors. Solid wall insulation is the largest underperformer, with over 13Mt of unrealised potential.



Behavioural measures not included.



	2005 technical potential	Reference case – Savings realised by end 2022 ($MtCO_2$/yr)
Solid wall	14.02	0.95
Cavity wall	5.75	3.00
Loft (<100mm)	2.66	0.98
Floor insulation	1.38	0.20
Other insulation	2.49	0.94
Glazing – single/old double to 2006 building regs *	6.33	2.89
Glazing, regs. to best practice	3.64	0.33
A-rated condensing boiler	9.88	9.16
Heating controls and insulation	2.6	0.62
Lighting	3.3	0.51
Cold/wet appliances	6.67	1.01
Ovens and hobs	1.38	0.16

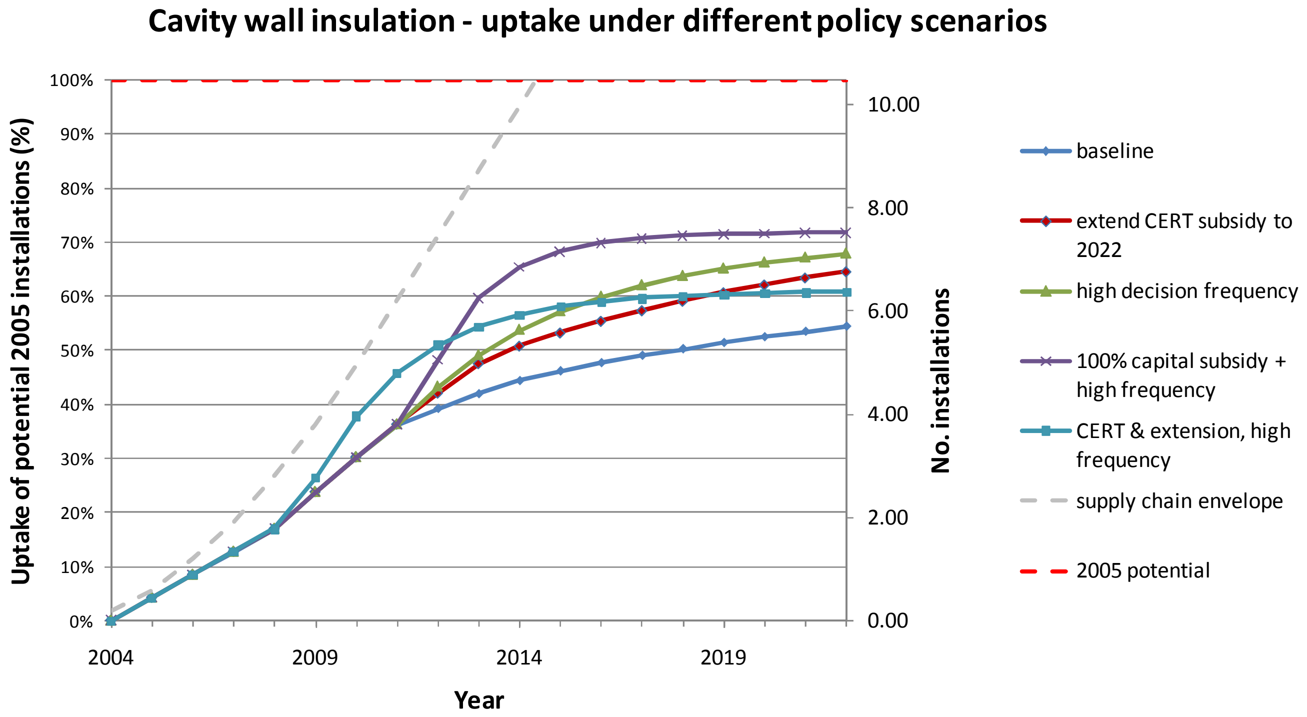
Note that in the following table the model reference case is typically lower than the CCC's previous reference scenario estimate. These differences arise from the methodologies taken to arrive at the predicted uptake curves. Former CCC work was based on S-curves fit to EEC and CERT predictions and historical data. This study by comparison considers the number of people coming forward each year and their willingness to pay for measures depending on the composition of the population and policies in place.

The lower reference scenario highlights the importance of policy in increasing uptake. More details regarding the reference case shown and the CCC scenario can be found in the appendix.

	Total installations 2005- 2022 (millions)		**CCC Residual (millions)**	**CCC Ambition for uptake of residual**	
	model reference case	Ref. (CCC)		low (mill.)	high (mill.)
Cavity wall	5.6	6.25	4.23	4.23	4.23
Solid wall	0.5 (of which 0.1 external)	0.34	7.37	0.44	0.74
Loft (<100mm)	9.2	12.93	0.111	0.106	0.106
Floor insulation	0.8	0.85	5.15	0.77	1.39
Glazing - single to 2006 regs *	3.6	6.01	1.88	0.38	0.75
Glazing - old double to 2006 regs*	9.9	13.54	2.23	0.45	0.89
Glazing, regs. to best practice	2.0	0	0	0	0
A-rated condensing boiler	18.41*	19.91	3.99	0.00	0.80
Lighting	5.8 (16.6 uncalibrated)	19.01	3.61	2.49	3.07
Cold/wet appliances	13.7 (33.4 uncalibrated)	22.85	27.10	10.27	23.0
Ovens and hobs	4.6	15.13	9.31	2.33	2.33

6.2 POLICY AND TECHNOLOGY SPECIFIC RESULTS

6.2.1 Cavity wall insulation



Reference Scenario
The rate of uptake in 2008 increases as a result of the expansion of the priority group in CERT. A greater percentage of the decision-making population receives the higher subsidy level and therefore is willing to pay for the measure. The rate of uptake reduces once the subsidy is removed (end 2011) in the reference case and payback periods for the consumer are then in excess of 3 years. The reference scenario uptake reaches 55% of potential by the end of 2022 and will eventually saturate at a level below 70%. The saturation level is defined by the laggards in the population (see appendix for further details).

Supply chain
The supply chain does not restrict uptake in the majority of policy scenarios. In extreme cases (100% capital subsidy or high decision making frequency from today) 1-2 years of minor constraint are observed prior to 2014.

Policy effects
The reference scenario identifies that there is scope to accelerate the rate of uptake.

In the near term (to 2015) extending and enhancing CERT is predicted to be relatively effective. Thereafter the laggard group begins to have an increasing constraint on uptake. To access this remaining potential, a strong intervention (such as mandation) would be more effective than generous grants (which could result in significant deadweight).

Extending the level of subsidy seen in CERT out to 2022 results in an additional c.1.1 million installations over the study period.

Increasing the rate of decision making from 8% (c. 0.84 million households per year) to 28% (c. 2.9 million households per year), however, produces a similar uplift (to the CERT extension) by 2022. This could be achieved through targeted marketing, or latching onto potential trigger points such as home redecoration/ installation of other products. Suppliers are in a key position to advertise such measures and a combination of marketing and subsidy, can explain the success the supplier obligation to date.

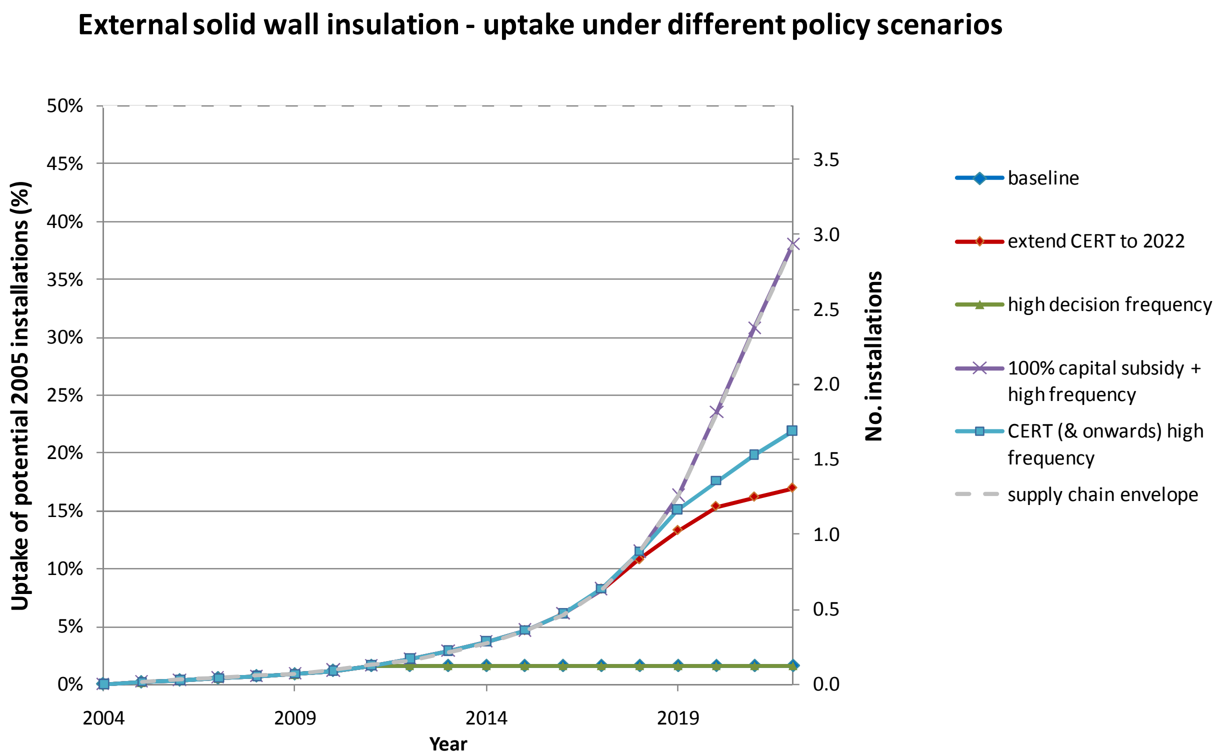
This combination is vital for continuing or increasing the rate of uptake. If high-decision making frequencies can be achieved during the CERT period uptake by the end of 2012 is increased by more than million installations. This uptake then becomes constrained by the supply chain.

Uptake of cavity wall insulation saturates at 73% of the 2005 potential, even under unrealistically strong policy support. The remaining 2.9 million properties are assumed to be owned by individuals identified as laggards. This group has little time or motivation to act to install energy efficiency measures, even with very short payback periods. The size of this laggard population is a key parameter and has been set at 28% of the population as discussed previously. To access these laggards would require strong intervention such as mandation. Note that increasing subsidy levels from those observed under CERT to a 100% capital subsidy does not raise the number of installations unless the problem of laggards in the population is solved. At present, a further increase in subsidy could therefore represent deadweight.

Further analysis, found in the appendix suggests that reducing the laggard population could increase uptake to approach 90% by 2022.

	Reference installations (millions), 2005-2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations due to policy (millions)			Absolute Potential no. installations in 2005	Absolute Potential MtCO2 in 2005
			extend CERT to 2022	high decision frequency	100% capital subsidy + high frequency		
Cavity wall	5.6	1.78	1.0	1.4	1.9	10.5	5.47

6.2.2 EXTERNAL SOLID WALL



Reference Scenario

External solid wall insulation has historically seen very low levels of uptake, and that which has occurred under the EEC1 and EEC2 phases has been primarily concentrated within the social housing sector. This can be explained, not only by the willingness to pay information of registered social landlords but also by lower installation costs (e.g. scaffolding) and hassle factor per dwelling associated with bulk installation, by lower capital costs per installation due to smaller on average dwellings and potentially due to less costly finishing requirements.

Subsidy support in CERT is predicted to be strong (c. 47% and 85% subsidy for non-priority group and priority groups respectively), however, over this timeframe installation rates are predicted to be constrained by the supply chain. No uptake is observed once this subsidy support is removed in 2011.

Supply chain

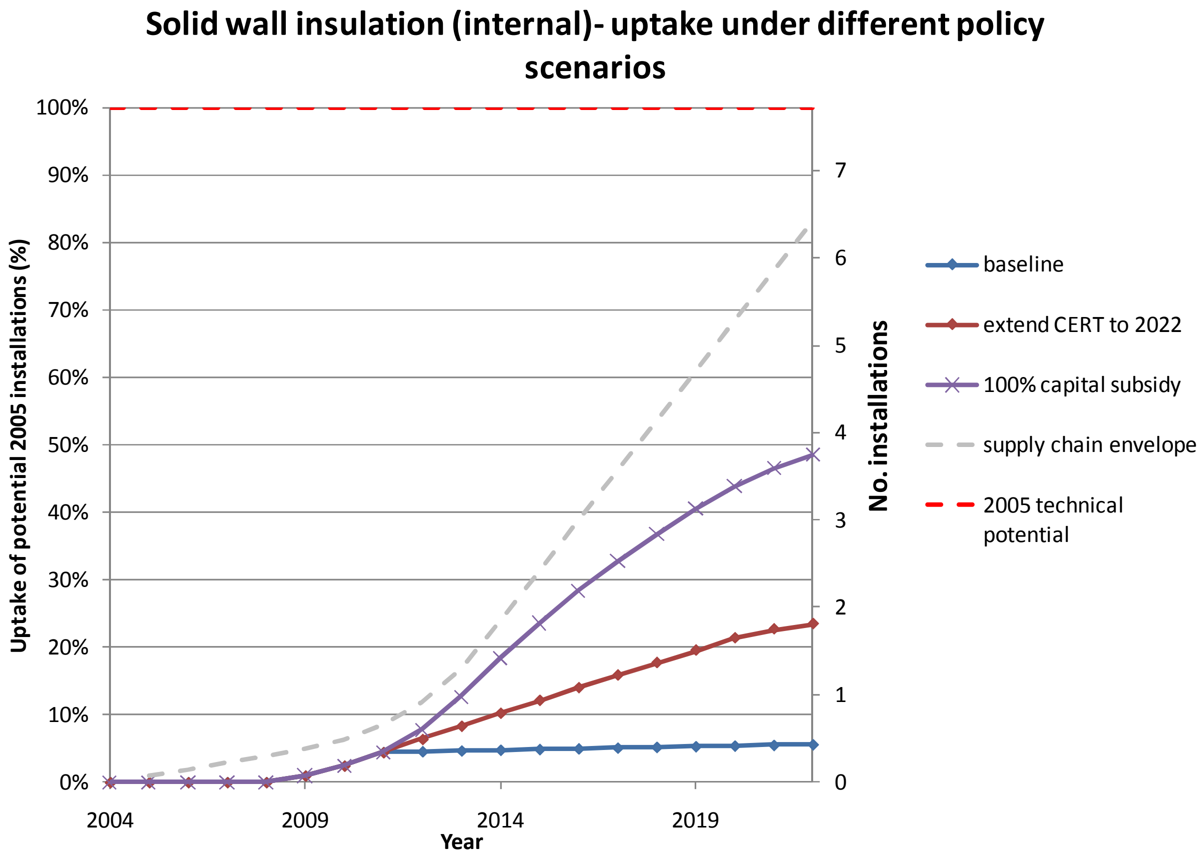
The starting base for the supply chain is currently low and predicted expansion rates over the CERT period are discussed in the supply chain section. We have allowed a strong rate of growth after the end of 2011 in line with a best case scenario indicated by the industry. This supply chain, however, inhibits uptake of external solid wall insulation for all policy scenarios where the strong CERT subsidy is continued.

Policy

No uptake is observed without capital subsidy support, even when decision-making frequency is increased. This measure therefore needs both strong policy indications to expand the supply chain as well as significant levels of capital support, such as those predicted in the CERT illustrative mix. Treating groups of properties (for example in a street-by-street approach) has the potential to effectively decrease the capital cost without requiring additional subsidy from the suppliers/Government. Such actions are also likely to locally increase the decision-making frequency for the measure.

	Reference installations (millions), 2005-2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations due to policy (millions)			Absolute Potential no. installations in 2005	Absolute Potential MtCO2 in 2005
			extend CERT to 2022	high decision frequency	100% capital subsidy + high frequency		
Solid wall (ext.)	0.1	0.05	1.1	0.0	2.2	7.7	13.38
Solid wall (int.)	0.4	0.00	1.3	0.0	3.21	7.7	13.38

6.2.3 INTERNAL SOLID WALL



Reference Scenario

Internal solid wall insulation has historically often been carried out to mitigate damp and mould in solid wall properties, rather than for the purposes of insulation alone. It is also frequently carried out on a room by room basis and as for external solid wall insulation, measures have generally been restricted to the social housing sector. The increase in anticipated subsidy level under CERT leads to a significant rate of uptake from a very low base at a faster rate than its external counterpart due to the lower capital cost requirement. Again, no uptake is observed once this subsidy support is removed in 2011.

Supply chain

As discussed earlier, the internal solid wall market appears likely to suffer from less restrictions than its external counterpart in terms of availability of installers and ability to expand production and installation. Less training is required and there is already a much stronger market for the product in the commercial sector. The 50% growth rate assumed therefore constrains the market in the early years but ceases to limit installation after 2014.

Policy

Internal solid wall installation suffers different barriers to its external counterpart. In this case hassle factors of redecorating, removing kitchens and bathrooms are so high that it can be assumed that insulation will only be carried out at present when redecorating or renovating a property. For this measure, therefore, decision frequency cannot be increased above 8%.

It is clear, however, that historical uptake rates are so low that even at this trigger point this measure has not traditionally been installed. Although lower than the equivalent external application, internal solid wall insulation still carries a high capital cost barrier. As for external insulation, no uptake is observed once subsidy support is withdrawn. It is also associated with loss of internal space within a property[34]. Rigid thermal boards, for example, should be at least 60mm thick to achieve best practice performance.

Subsidy support increase leads to a significant increase in installations during CERT period which continues if the support is not removed. The higher the rate of subsidy, the faster the installation rate, (until the supply chain constraint is reached). The restriction on decision-making frequency, however, ensures that even if the supply chain does not present a barrier, it would take 12.5 years to achieve 100% of the potential.

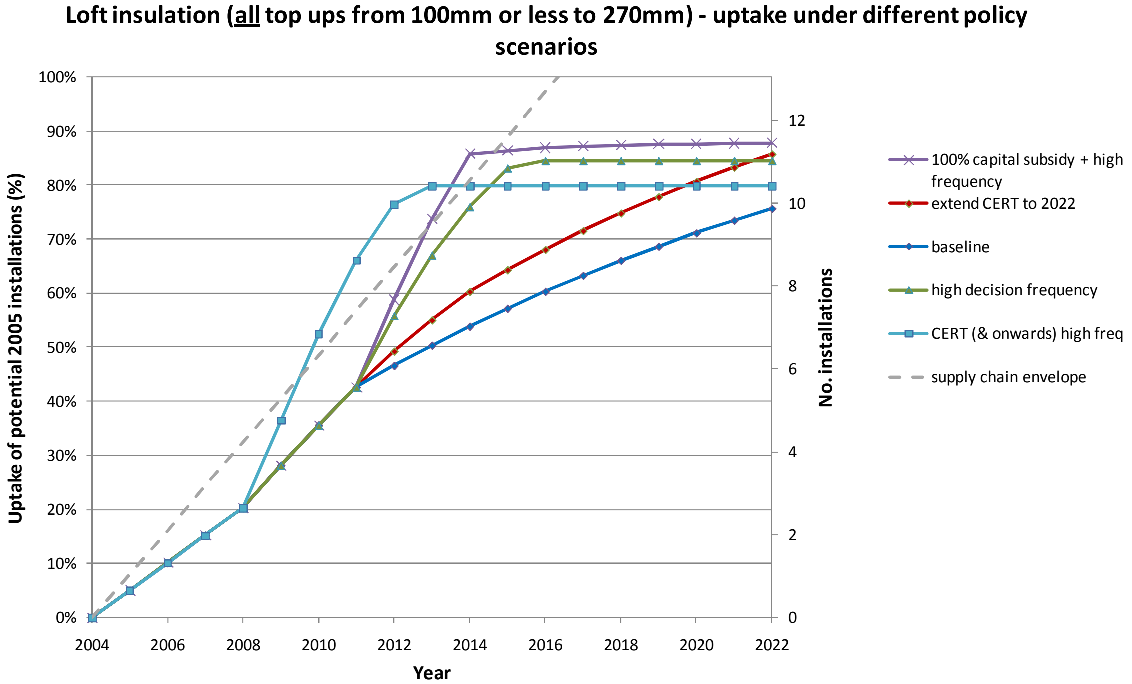
6.2.4 LOFT INSULATION

Predicting the uptake of loft insulation is complicated by:

- The division of the measure into varying depths of installation
- The potential for home-owners to install DIY installation rather than employ a professional installer.

Uptake of DIY loft insulations was much higher than anticipated over the EEC2 period (2005-2008) and therefore cannot be ignored. DIY represented over 30% of the total installations during the period[35] (c.800,000 installations). Since this measure has a different cost and time requirement to professional installation it has been modelled as a separate technology, with energy savings taken from the CERT illustrative mix.

The results presented here represent all measures (DIY and professional) where the starting insulation in the loft was 100mm or less. The remainder of the market is considered much harder to access.



Reference Scenario

Uptake of loft insulation is historically strong and is estimated to be already at 30% by the end of this year. Uptake under the reference scenario reaches c.76% of the potential without further policy intervention beyond the end of CERT. This is helped significantly by the performance of the DIY installation market.

[34] A value for loss of space has not been allocated in this approach due to its subjective nature and therefore should be recognised as an additional restriction on uptake.

[35] Based on $45m^2$ insulation per loft

Supply chain
The supply chain envelope shown is based upon the limit of 1.057 million installations per year suggested by ESD (see earlier). The rate of installations can be seen to exceed this proposed limit if the decision-making frequency is increased. This is a complexity due to modelling both professional and DIY installations. The material capacity of the industry will need to be expanded beyond this limit if the installation rates shown are to be achieved.

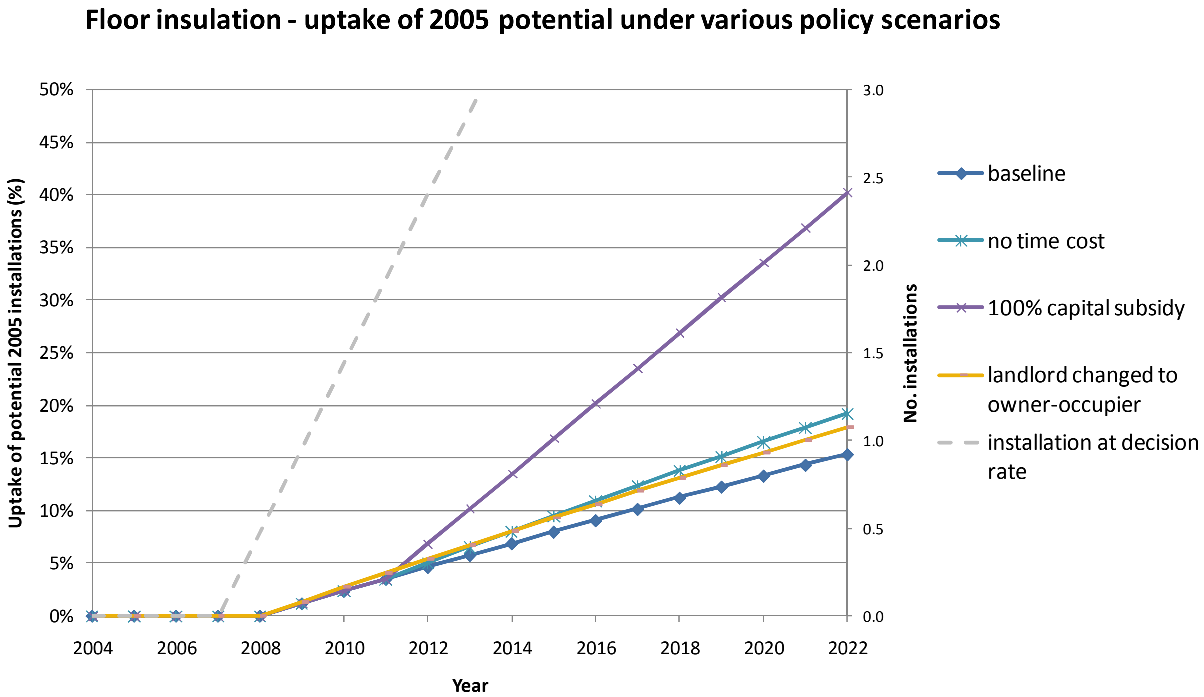
The government's proposal to install all easy to treat measures by 2015 requires the installations per year to at least follow this supply chain envelope and achieve access to the laggards in the population.

Policy

An extension to CERT could achieve c.86% of the potential by 2022. Increasing the decision-making frequency can achieve this potential at an earlier date (e.g. by 2015 for a high decision-making frequency of 28% for owner-occupiers) but fails to access all of the laggards in the population.

	Reference installations (millions), 2005-2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations due to policy (millions)			Total Potential no. installations in 2005	Total Potential $MtCO_2$ in 2005
			extend CERT to 2022	high decision frequency	100% capital subsidy + high frequency		
Loft insulation (<100mm)	9.2	2.65	1.3	1.8	2.2	13.0	2.53

6.2.5 FLOOR INSULATION



Reference Scenario
Floor insulation has not been explicitly included under CERT nor under EEC 1 or 2 and there is little information as to the historical rate of installation. The reference scenario predicts 15% uptake by the end of 2022, with no subsidy offered.

Policy
The hassle involved with removing the floor in a property means that as for internal solid wall insulation, the decision-making frequency cannot be increased above 8%. An extremely generous 100% capital subsidy results in a much higher rate of uptake (although at a lower rate than the decision rate).

A significant fraction of DIY installations are undertaken and hence there is an increase in installations by c.5% when the time cost is removed. Switching landlords to behave as owner-occupier has a small but noticeable effect on the reference scenario uptake.

	Reference installations (millions), 2005-2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations from policy (millions)			Total Potential no. installations in 2005	Total Potential MtCO2 in 2005
			extend CERT to 2022	high decision frequency	100% capital subsidy + high frequency		
Floor	0.85	0.00	0.0	0 (N/A)	1.4	6.0	1.31

6.2.6 BEST-PRACTICE GLAZING

Double glazing purchases can be subdivided into two categories:

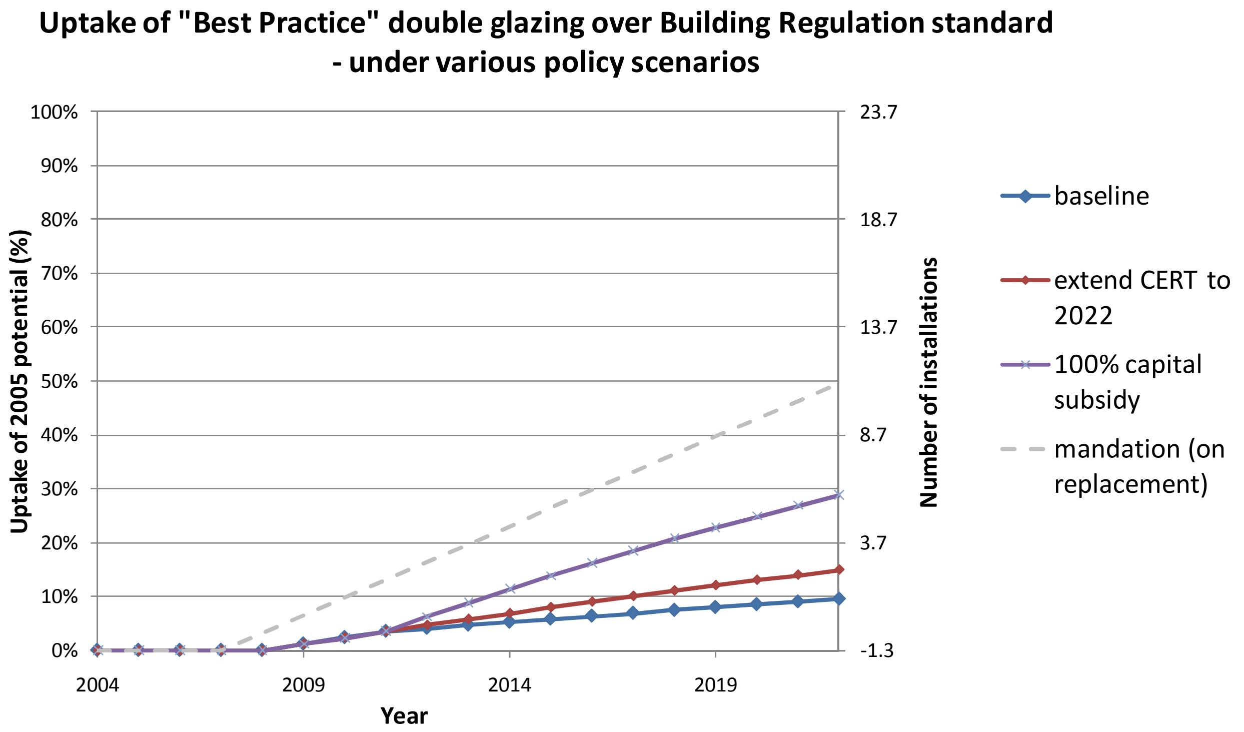
- Replacing old windows with E rated or equivalent glazing specified in Part L of the building regulations (area weighted average U-value equivalent to 2.2W/m^{2}K)
- Replacing old windows with best-practice glazing, here taken as double glazing with U-value of 1.2 W/m2K[36], instead of that mandated by building regulation. The energy, CO2 savings and cost for this measure are only counted as the additional cost/benefit over and above the Part L standard.

E rated double glazing is mandated during renovation/extension work and therefore uptake of single to E rated double glazing is at the current rate of replacement for windows (0.78 million home upgrades per annum[37]) and is unaffected by the modelled policies. It will take c.30 years to replace all the 2006 stock at this rate. It is possible to repair windows without replacement or gain an exemption from Part L and therefore this represents an upper limit to this mandation policy.

The remainder of this section is concerned with the uptake of best practice glazing over and above the E rated or equivalent specified in the building regulations. We assume that at the point of replacement, individuals have the opportunity to upgrade to a best practice window for an additional cost of c.£500[38] minus any subsidy.

Reference Scenario
The graph below examines the potential for uptake of best practice double glazing over the building regulated equivalent. The reference scenario assumes there has been next to no uptake to date of this technology. The illustrative mix predicts a CERT subsidy will be offered on E (building regulations) to C rated glazing (U-value of 1.5) and the same level of subsidy is applied here. This results in an uptake of 10% by the end of 2022.

[36] in line with BRE "future double" and chosen for consistency
[37] Assumes 10 windows per property and based on sales from Palmer Market Research
[38] From BRE



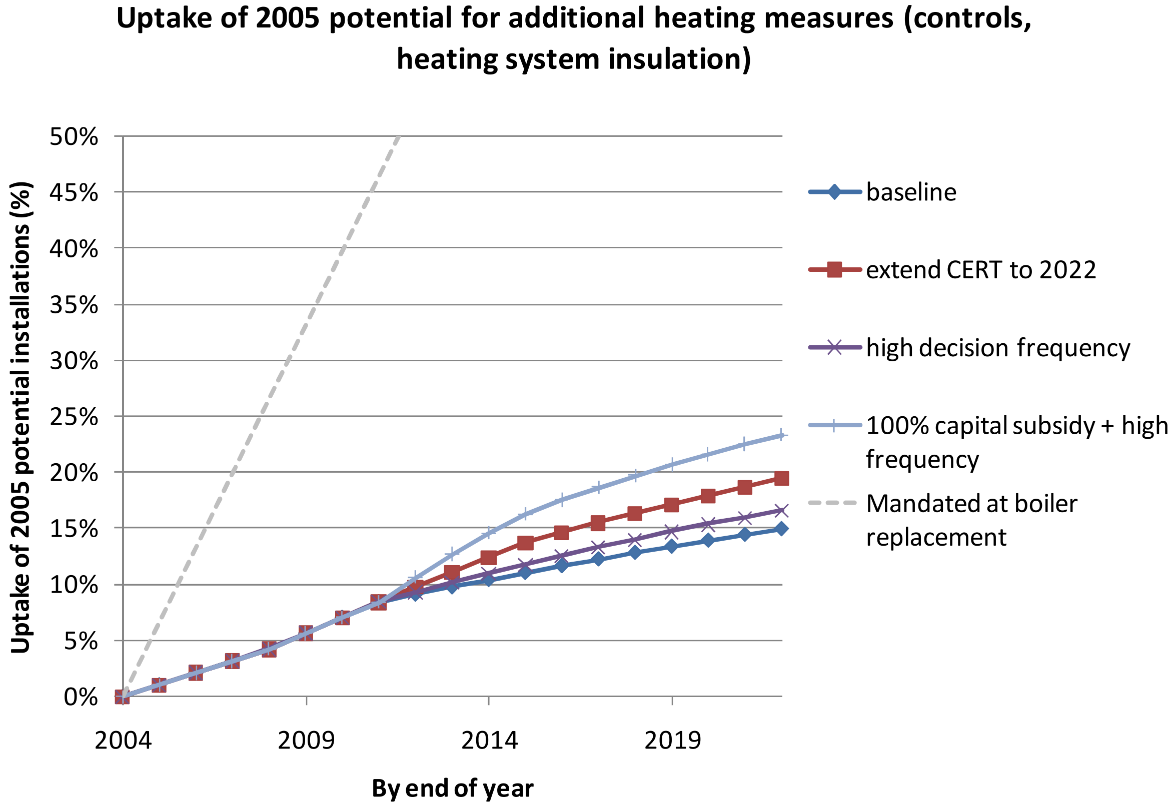
Supply chain
We do not assume any supply chain limits in the modelling in this sector. In reality there is a low market for these "best practice" windows in the UK at present, and a lack of available information to consumers.

	Reference installations (millions), 2005-2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations from policy (millions)			Total Potential no. installations in 2005	Total Potential MtCO2 in 2005
			extend CERT to 2022	high decision frequency	100% capital subsidy		
Glazing (BP)	2.0	0.00	1.2	0.0	4.3	23.7	3.46

6.2.7 BOILERS & HEATING CONTROLS

Boilers
A-rated condensing boilers are assumed to be mandated, and uptake therefore occurs at the replacement rate of the technology. This policy began in 2005 and it is predicted that 94% of the stock will have been replaced by the end of 2022 without any further policy intervention. We assume that early replacement of boilers involves too much hassle and financial cost to occur without major policy intervention, and this is not modelled further.

Heating Controls



Reference Scenario
The installation of heating controls is a discretionary decision carried out by the householder, with uptake modelled as being dependent on the simple payback and absolute capital cost concerned. The reference scenario predicts the uptake of heating controls at a rate much slower than the rate of replacement for boilers.

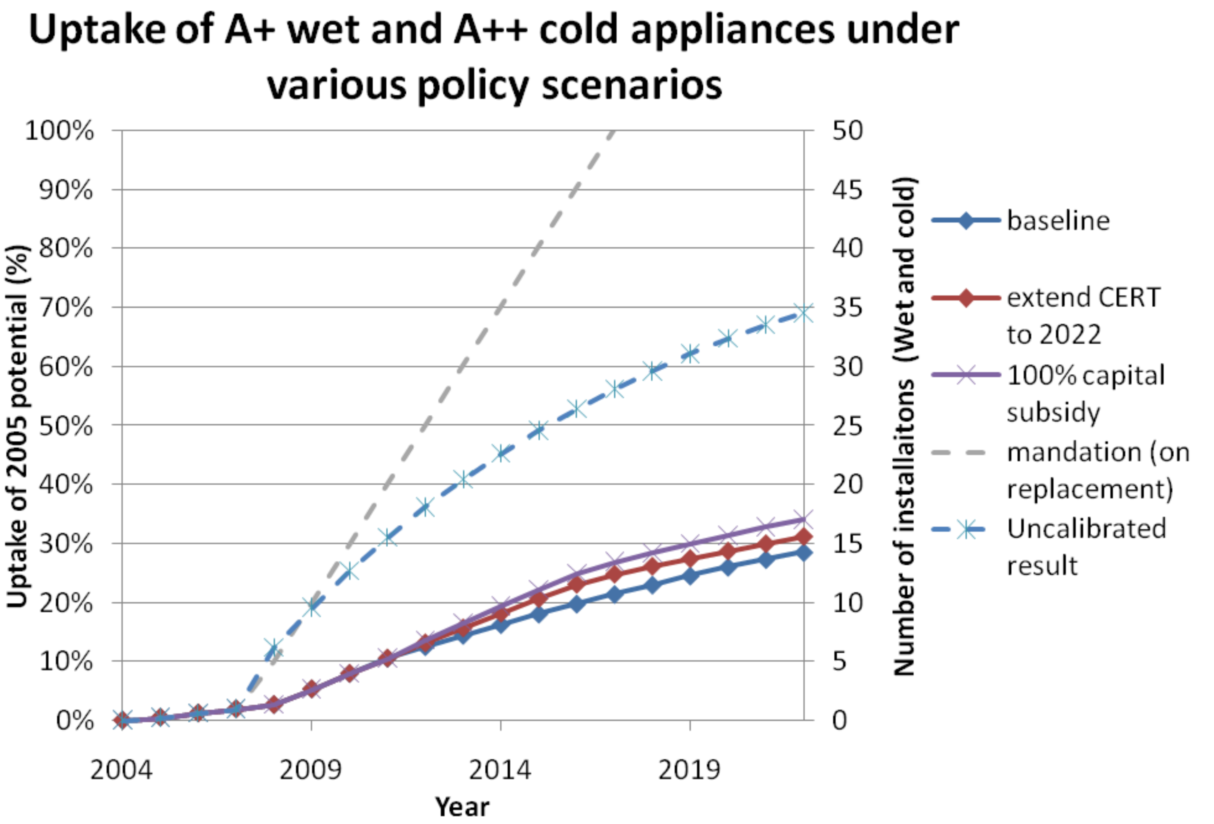
BRE estimates for annual fuel savings for TRVs are extremely low, resulting in long payback times and low uptake. The addition of hidden and missing costs to controls also generally retards the payback periods by several years.

Policy
The poor payback of this technology is behind the low uptake and limited effect of policies modelled. Mandating the technology during boiler replacement would be more effective than generous grants, although if extra cost were incurred this could have unintended consequences in reducing the frequency of boiler replacement (such interactions are not modelled). Lack of information is seen as a barrier to adoption and it may be that installers could be incentivised to highlight the benefits of controls (e.g. advice fee paid for supplying control quote with boiler quote)

Reference installations (millions), start 2005 to start 2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations from policy (millions)			Absolute Potential no. installations in 2005	Absolute Potential MtCO2/a in 2005
		extend CERT to 2022	high decision frequency	100% capital subsidy + high frequency		
5.8	1.71	1.7	0.6	3.2	40.3	2.57**

**Remaining potential for room thermostats indicated by TACMA suggests this number could be increased by 4MtCO_2

6.2.8 APPLIANCES: White goods



Reference Scenario

The uncalibrated reference scenario uptake is predicted to be relatively strong over the period to 2022. This level of uptake can be seen as an upper bound to the uptake of A+ and A++ appliances. Calibration was then applied to match historical sales although such appliances have only recently come to market. This calibration results in a market penetration of c.30% by 2022. The uncertainty therefore lies in how well the early years of sales of A++ and A+ cold and wet appliances are representative of the future performance of these technologies. The relatively recent introduction of these products and lack of knowledge/wide availability may cause the calibration to produce underestimates of future uptake. The calibrated and uncalibrated extremes can therefore be seen as a lower and upper bound.

Uptake of A rated products was rapid over the period 2002-2008 and is underestimated by the early years of observed sales.

If, however, the differential between A+ and A rated products turns out to be small compared to the differential for A rated products in this case, uptake is likely to be more restricted.

Supply chain

There are assumed to be no supply chain constraints to these technologies as internationally traded goods. The limit of uptake is therefore defined as the rate of replacement if these technology ratings were mandated. Uptake could be completed by c.2017.

Policies

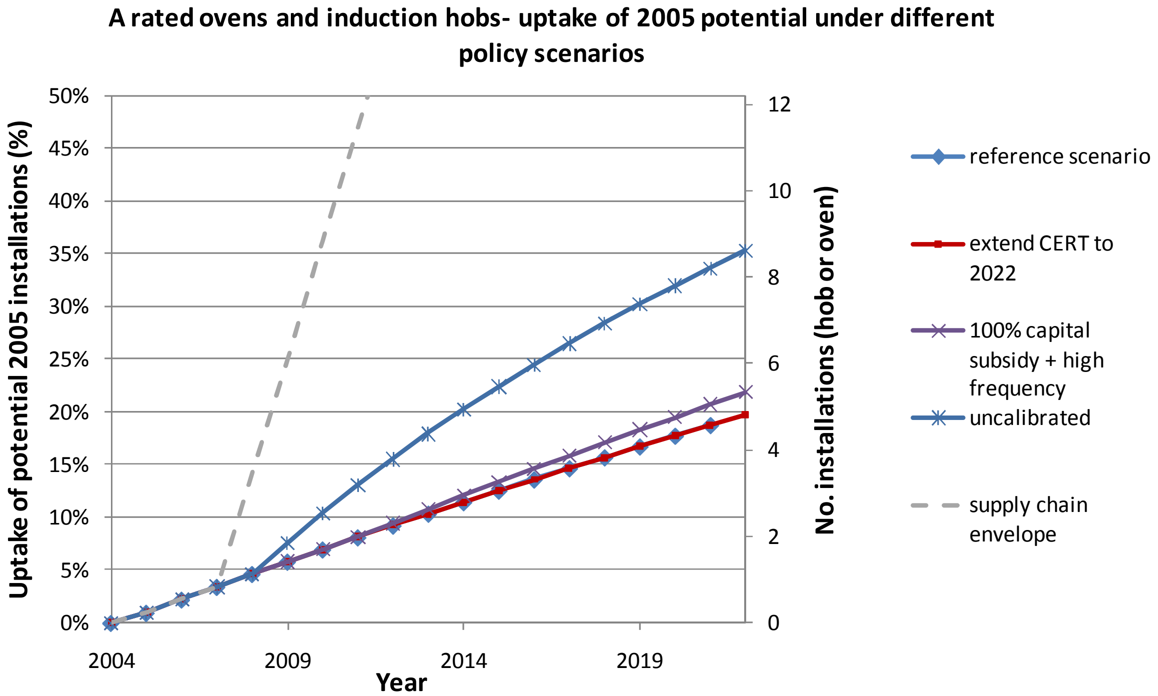
The effect of policies on appliances is relatively limited in this approach. This could reflect:

- The irrelevance of hidden and missing costs in this sector
- Ratings being perceived as a quality indicator
- Brand loyalty/aesthetics taking precedence
- Decision heavily influenced by retailer/seller rather than the consumer

	Reference scenario installations (millions), lower bound 2005-2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations from policy (millions)			Total Potential no. installations in 2005	Total Potential MtCO2 in 2005
			extend CERT to 2022	high decision frequency	100% capital subsidy		
appliances	13.7	1.32	1.3	0.0	2.7	50.0*	3.89

*Double the number of households

6.2.9 APPLIANCES: Cooking

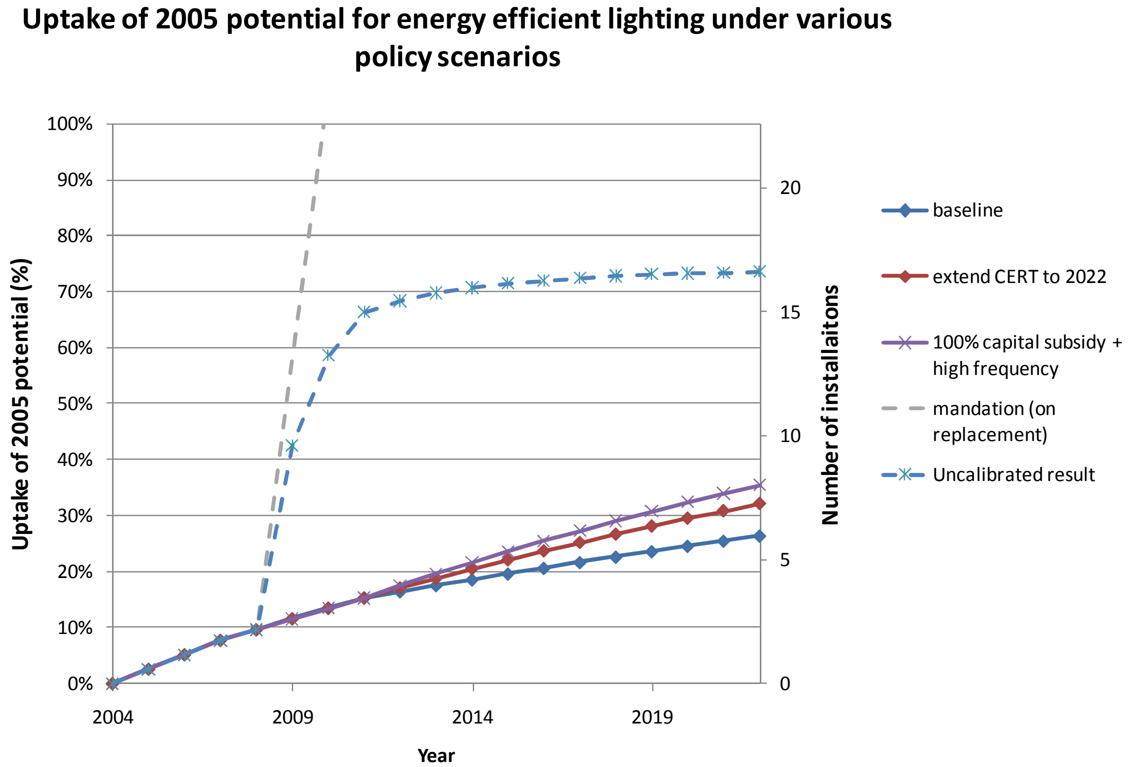


Reference Scenario, Supply Chain and Policies
As with A-rated appliances, the effect of policy on efficient ovens is limited.

	Reference installations (millions), 2005-2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations due to policy (millions)			Total Potential no. installations in 2005	Total Potential MtCO2 in 2005
			extend CERT to 2022	high decision frequency	100% capital subsidy + high frequency		
Ovens and hobs	4.6	1.14	0	0	0.5	24.4*	0.80

*Can install A rated electric oven and/or induction hob (i.e total potential is the sum of electric oven potential (12.7m) and electric hobs (11.8m electric hobs)

6.2.10 Lighting



Reference Scenario
Historical data for uptake was taken from the Eoin Lees assessment of EEC2. It was noted that CFL installations according to householders over the period stood at 16.3 million bulbs compared with 102 million according to suppliers. Here we use the householders' figures for installation rate as we are concerned with CO_2 savings. We assume the average household has at least 10 bulbs which could be replaced by CFLs.

As with white goods, lighting required calibration to match this historical installation rate. The uncalibrated result is also shown here for completeness. It would represent an upper bound on uptake if the non financial barriers (such as perceived lack of utility and flexibility) were removed.. In this limit the last 28% of the population (i.e. the laggards) cannot be accessed due to non-financial reasons. This laggard estimate fits well with EU studies suggesting 30% of households do not wish to install CFLs.

Policy

Short lifetime of tungsten bulbs they are replacing and international market for bulbs ensures that if the appropriate mandation were imposed, full saturation of the market could be achieved in only a few years[39]. This would currently, however, require many householders to change some of their electrics and fittings to accommodate CFLs. The phasing-out of inefficient bulbs (and fittings which do not accommodate their energy efficient equivalents) allows time for adaptation and access to the laggard population who would not otherwise be reached.

	Reference installations (millions), 2005-2022	Installations achieved by end 2008 (millions)	Total no. ADDITIONAL installations due to policy (millions)			Total Potential no. installations in 2005	Total Potential MtCO2 in 2005
			extend CERT to 2022	high decision frequency	100% capital subsidy + high frequency		
Efficient lighting	5.8	2.18	1.2	0	1.9	22.6	1.93

[39] Exceptions – bulbs with low usage

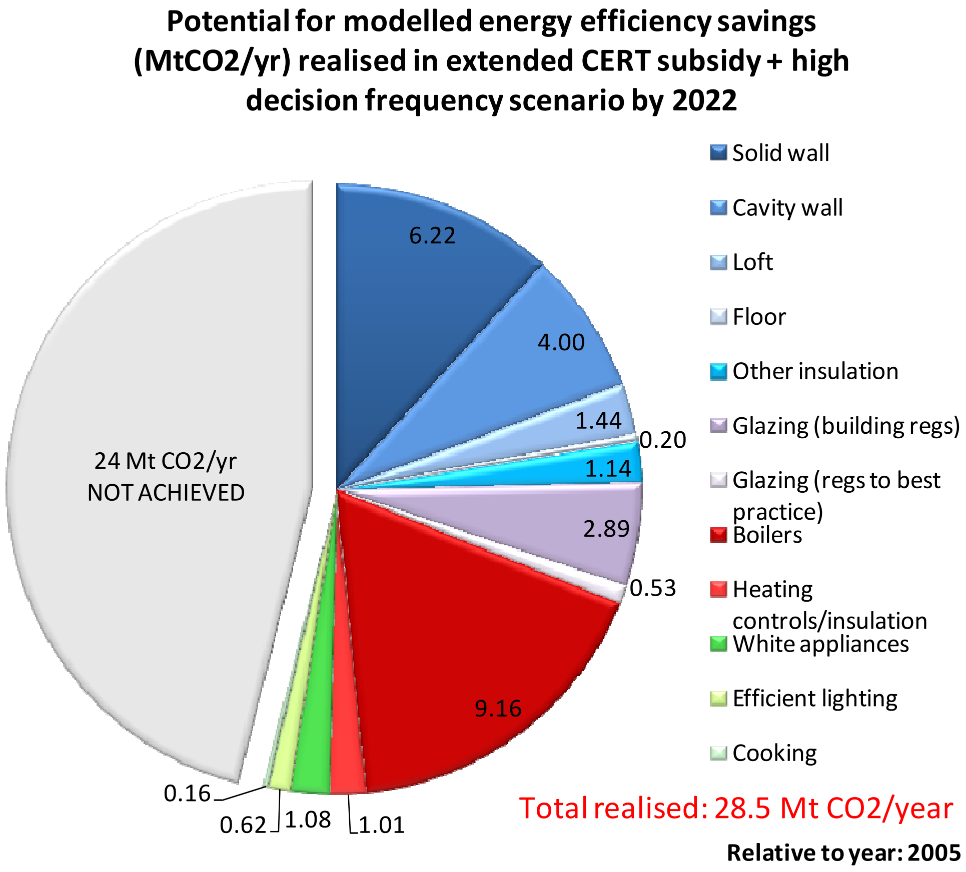
7 CONCLUSIONS: DOMESTIC SECTOR

Analysis carried out here suggests that the reference case leaves nearly two thirds of the 2005 potential unrealised. This reference scenario does not include many of the more recent policy announcements and therefore we consider here whether the current policies are likely to access a significant proportion of the remaining potential and what else could be done to realise greater ambitions.

The following graph may be seen as more representative of the government's current policy than the reference scenario, as it includes an expanded CERT programme which is extended out to 2022. Note that to achieve the expanded CERT programme will almost certainly require a more active marketing programme, and this is represented as a higher decision frequency.

With this in place, uptake is significantly improved, achieving an additional c.8MtCO_2 savings per annum over the reference scenario. Support levels, particularly in terms of capital support for solid wall insulation are required to be highly significant to achieve this result. Half of the potential, however, is still not realised as a result of:

- Supply chain limits and large capital requirements for hard to treat measures
- Laggards in the population
- Technology replacement rates (e.g. long periods between window replacement)



Easy to treat measures

The Government has recently proposed ambitious goals to complete "easy to treat" measures by 2015, and has extended support of the supplier obligation. In order for this goal to be achieved, uptake of cavity wall and loft insulation would need to follow the supply chain limits predicted by ESD.

Uptake under the EEC programmes has historically been strong and is predicted to continue under CERT, however, this ambition is demanding and it is clear that householders will need to come forward at a faster rate to make decisions if this target is to be achieved. This requires an increase in targeted marketing or press coverage of the measures, their potential benefits, and promotions available to the public.

We suggest here that laggards in the population (circa 20%-30%), with low willingness to pay for energy efficiency measures are likely to limit this goal and retard uptake. There is a key uncertainty here as to how this percentage will evolve through time and how behaviour in this group can be transformed. In order to access this population and achieve 100% saturation without such a change, mandation or regulation would be required (for example enforcing the installation of measures where practicable when properties are bought or sold).

Hard to treat measures
Solid wall insulation represents the most significant measure in terms of technical potential for CO2 savings, however uptake is generally low.

Relative to the current work, previous analyses of HTT measures underestimated capital costs. Also, the disruption factor of these technologies is high. Overall the predicted effect is to limit the uptake to a level which is far below the decision-making frequency.

Increasing the decision making frequency has limited effect as uptake is constrained by high cost. Generous capital grants are shown to have an effect on the market. Even with such policies in place, uptake is constrained by the supply side (particularly for external SW insulation).

Appliances and lighting
The purchase of lighting products and appliances is dominated by non-financial related issues such as brand loyalty (for appliances), or perceived loss of utility and poor function related to the incumbent (in the case of low energy lights). The model was calibrated to achieve good correlation with historic uptake.

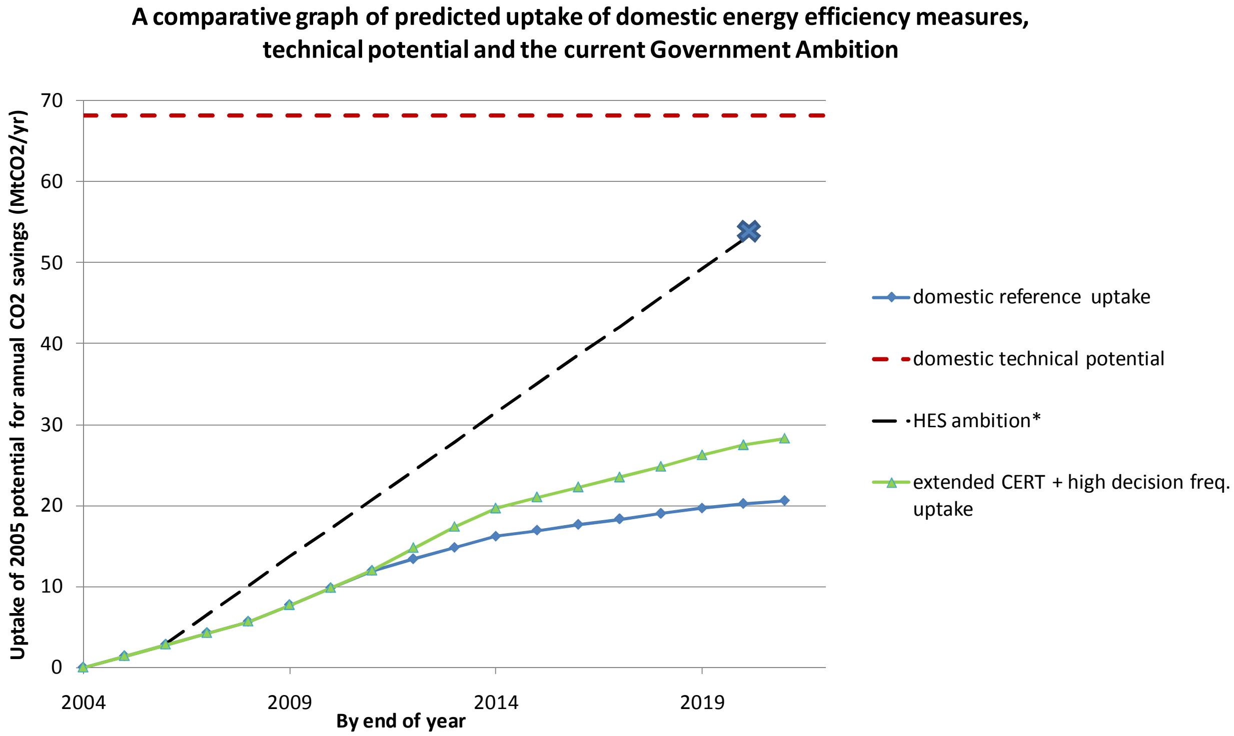
In energy efficient lighting, all modelled policies achieved limited additional uptake, relative to the potential uptake if the incumbent technology was phased out. Improving consumer attitudes on CFL's would be very effective, but could be very time consuming. Regulation and the structured phasing out of incandescent bulbs is recommended as this would have a significant effect in relatively short time.

Comparison with Government ambition

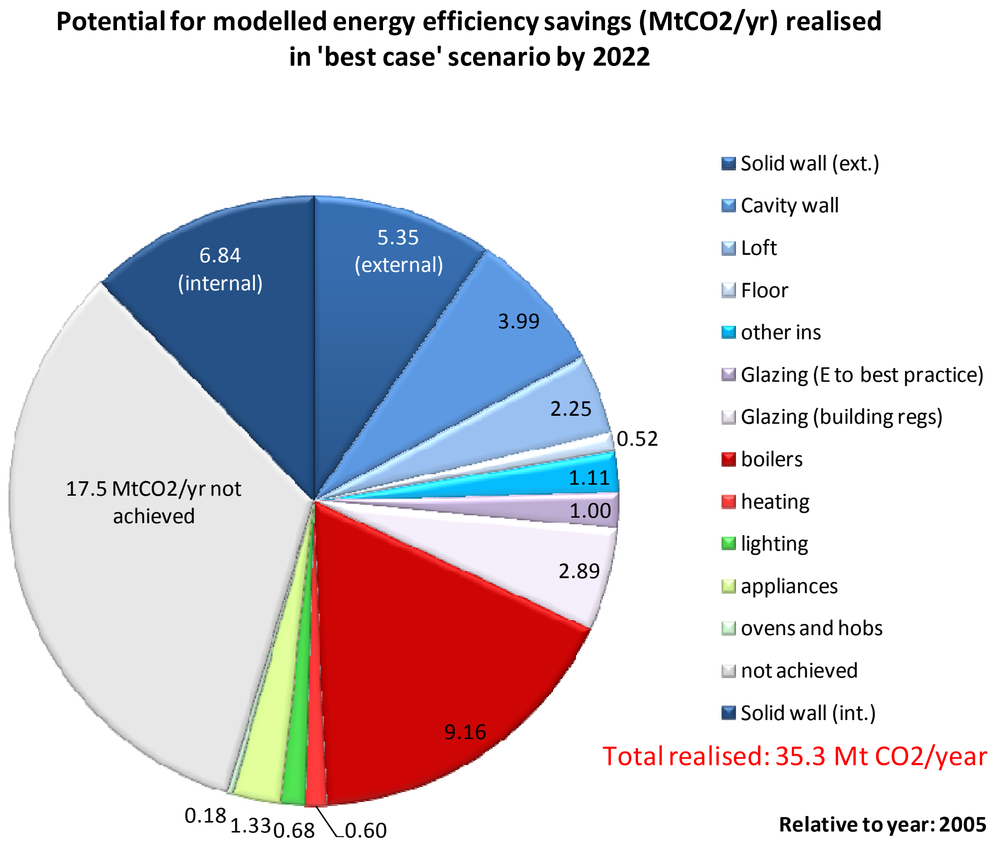
The level of ambition identified by DECC for the Supplier Obligation programme of 16-20Mt of annual CO_2 savings by 2020 falls within the estimated uptake projections found within this study[40].

The Heat and Energy Saving Strategy (HES) consultation document released earlier this year, however, sets an ambitious target of a reduction of 50 $MtCO_2$ savings per annum by 2020 as a result of policies set out in the document, the Supplier Obligation and the new Community Energy Saving Programme. Whilst this document also covers the implementation of renewable heat, combined heat and power (CHP) and district heating systems[41], this still represents an ambitious target.

[40] N.B. Not all technologies modelled overlap with the Supplier Obligation programme
[41] A technical CHP potential for high heat density areas was identified as 9.8Mt CO_2 per annum for natural gas CHP.



This target is hard to obtain in our modelling by energy efficiency measures alone, as a combination of supply chain restrictions on technologies such as solid wall, low decision-making frequency (e.g. for replacement heating controls) and laggards in the population (e.g. for the last remaining installations of cavity wall insulation, see appendix). Our optimistic policy scenarios, catered for each technology achieve a saving of 35 $MtCO_2$ per annum by 2022.



8 ACTIONS

Each barrier has a corresponding required action, existing policies which attempt to deal with this barrier.

	Barrier	Potential action	Current/future policy
Info.	Inaccurate/lack of knowledge of current energy consumption/ technology costs	• Supplying independent, high quality, targeted information directly to consumers. • Better billing and/or real time displays.	EST (+ suppliers through CERT)
Inertia	Lack of engagement from some consumers	• Supplying independent, high quality, targeted information directly to consumers.	EST (+ suppliers through CERT)
Financial	Capital cost/ access to finance	• Capital subsidy or loan at low interest rate	CERT, reduced rate VAT, regional schemes (e.g. Warm Front)
	Long payback period cf. consumer horizon	• Reduction of payback through subsidy • Incorporation into a loan (e.g. against future energy savings).	See proposals in HES consultation
Hidden costs	Time input required for project identification, appraisal and commissioning	• Supply service free or at low charge to identify and co-ordinate project up until installation. • Provide clear labelling/certification schemes to enable consumers to quickly identify suitable products.	MTP/ EU Energy Label Scheme
	Disruption (e.g. supervision time required for installation)	• Improve speed of installation to minimise installation. Co-ordinate with consumer to find least disruptive time. • Provide a service to supervise installation.	
	Additional engineering required (e.g. scaffolding, redecoration)	• Reduce additional costs through timing deployment to fit with renovation/redecoration work. • Co-ordinate potential adopters to reduce e.g. scaffolding costs.	
Split incentive	Landlord - tenant split incentive	• Clear guidance to tenants/landlords about energy efficiency alterations to property, can the tenant initiate this, where does responsibility lie and how can costs be fairly allocated? • Reduce payback period to within duration of tenancy or create an innovative financing programme to recuperate some of the cost through fuel savings over time.	Energy Performance Certificate, Landlord's energy saving allowance
Commision/ handover	Poor commissioning and/or handover leads to poor operation of system	• Minimum standards of certification for installers/installation processes. • Simplification of system design to enable quick, effective handover. • Improve quality of training for installers.	
Use	Ongoing management/supervision required	• Simplify systems (e.g. controls) to require minimum management and operation where possible without a manual. • Default setting to off or to a target temperature below the average (e.g. 18 C).	
Loss of utility	Loss of utility of, e.g. space for loft and internal SWI	• Design of standard systems to minimise loss of utility (e.g. enables use of loft space)	

Part 2: NON-DOMESTIC SECTOR

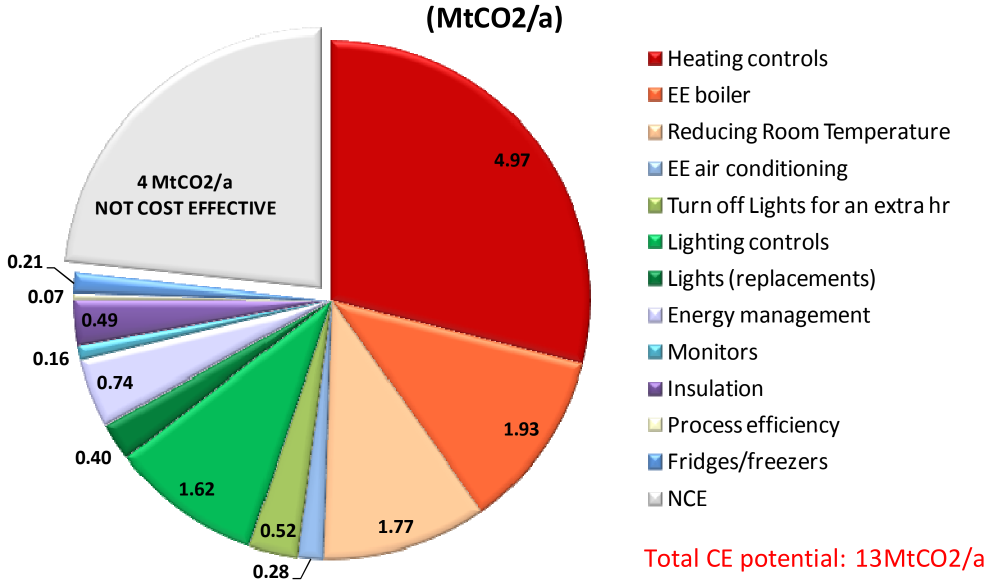
This study considers a set of technologies and measures, in line with previous modelling work by the Climate Change Committee, and analyses the likely uptake of these over the period 2008-2022.

We will in turn examine the current state of the market, the decision-making process for the installation of these measures and the barriers to their installation. Finally we examine the potential influence of current and future policy or actions to improve uptake, and compare these results to the reference scenario of the CCC and historical uptake data.

The measures under consideration, and their associated maximum technical potential were defined by work using the BRE N-DEEM model. N-DEEM splits each technology into cost effective and non-cost effective installations and provides outputs in this form. We primarily consider the uptake of cost-effective measures in this study.

It is not possible to alter this technology list, alter the division, or assess the accuracy of these values given the level of transparency of N-DEEM and the scope of this project.

Absolute technical potential for annual CO2 savings from cost effective non-domestic energy efficiency measures in 2007 (MtCO2/a)



Non-Domestic measures			
Heating	Heating - Programmable Thermostats High	Equipment	OffEq - Most EE Monitor/pc
	Heating - TRVs Fully Installed		Most EE freezer
	Heating - most EE boiler		Most EE fridge-freezer
	Heating - More efficient air conditioning		Most EE fridge
Lighting	Lights- Most EE Replacement 26mm	Insulation	Most EE cavity wall insulation
	Lights- Most EE Replacement Tungsten		Most EE flat Roof insulation
	Lights - HF Ballast		Most EE pitched roof insulation
	Lights - Metal Halide Floods		Most EE External cladding (SWI)
	Lights - IRC Tungsten-Halogen - Spots		Most EE double glazing
Lighting controls	Lights - Basic Timer	Behavioural	Heating - Reducing Room Temperature
	Presence Detector		Heating - Optimising Start Times
	Stairwell Timer		Lights - Turn off Lights for an extra hour
	Lights - Sunrise-Sunset Timers		Monitors - Energy Management
	Lights - Light Detectors		Computers - Energy Management
Other	Compressed air		Printers - Energy Management
	Variable Speed Drives		Photocopiers -& faxes Energy Management
	Motor - 4 Pole Motor - EFF1 replace 4 Pole		Vending Machines Energy Management

1 STATE OF THE STOCK/ EXISTING DATA

Information regarding the state of the existing non-domestic building stock more limited compared to the domestic sector. The basis for non-domestic stock models currently in development (Carbon Trust and the CaRB project) and in use (N-DEEM), is a comprehensive database of energy surveys produced by Sheffield Hallam University[42] commencing in the early 90's. This dataset is now over 10 years old and as such some forms of building energy end use are likely to have changed significantly (e.g. IT equipment and servers). Defra's Market Transformation Programme provides some insight into the historical uptake and predicted sales of AC systems, commercial lights, catering and IT equipment, however, outside the programme, the penetration of energy efficiency measures is poorly understood.

1.1 Technical potential and associated costs

Input assumptions on cost were taken from BRE's work based on N-DEEM. All costs are given as the cost of implementing the "cost effective" fraction of the measure across the stock, and have an associated GWh of energy saving. It has not been possible to link these figures to installations, primarily due to the variability of the stock in the non-domestic sector.

For each technology the simple payback was calculated based upon the capital cost per GWh of predicted energy savings and fuel mix. Hidden and missing costs were represented by a percentage of the capital cost unless otherwise stated and were set at 10-30% of the capital cost. This figure is derived from work by Enviros on hidden and missing costs.[43]

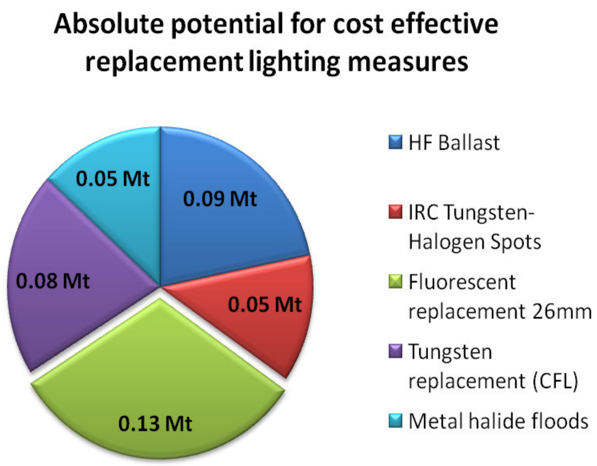
1.1.1 Commercial replacement lighting

The commercial lighting market is diverse with major differences between sectors (e.g. retail versus offices). The primary lighting types and their potentials are discussed below. The total technical potential for replacement lights in 2007 was given as 1.6MtCO_2 per annum of which 0.4Mt was cost-effective.

Fluorescent lamps

Fluorescent lamps are widely used in offices, public sector buildings and retail outlets with 26 mm (T8) halophosphate fluorescent tubes dominating the market. Triphosphor lamps are assumed, in this study to be the current energy efficient replacement for halophosphate tubes and according to the MTP, price differences between the two products are insignificant compared to the price of the luminaire[44].

There is, however, often no significant economic benefit to replacing halophosphate lamps unless significant refurbishment is taking place according to the MTP. This is echoed by the large fraction of non-cost effective measures in the N-DEEM estimates.



GLS lamps

GLS lamps are used in some sectors (e.g. hospitality sector) and much of their supply is likely to be covered by the domestic supply chain. Purchases are likely to be influenced by UK policy decisions to phase out the most inefficient bulbs in the domestic sector, and suffer from similar barriers. In addition it is unlikely that after refurbishment, GLS lamps will be permitted under 2006 part L2B building regulations[45].

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[42] Mortimer N D, Elsayed AM, Grant J F, 2000, "Detailed energy surveys of nondomestic buildings" Environment and Planning B: Planning and Design **27** 25 -32

[43] Enviros Consulting Ltd (2006) Review and development of carbon dioxide abatement curves for available technologies. Energy Efficiency Innovation Review for Defra

[44] Policy Brief: Improving the energy performance of commercial lighting products, Defra (2008)

[45] Part L2B applies to buildings greater than 1000m2, for any extension, and for initial provision or increase in installed capacity of fixed building services. Measures with a simple payback <15 years are considered economic in this regulation.

Halogen lamps
Metal halide lamps have significantly higher cost than tungsten halogen lamps that they are likely to be replacing and are not designed to plug into traditional halogen fittings. They are able, however, to achieve c. 3 year payback periods on the additional capital cost and have a significantly longer lifetime than their standard halogen equivalents.
Efficient infra-red halogen models have not yet made significant market penetration[46].

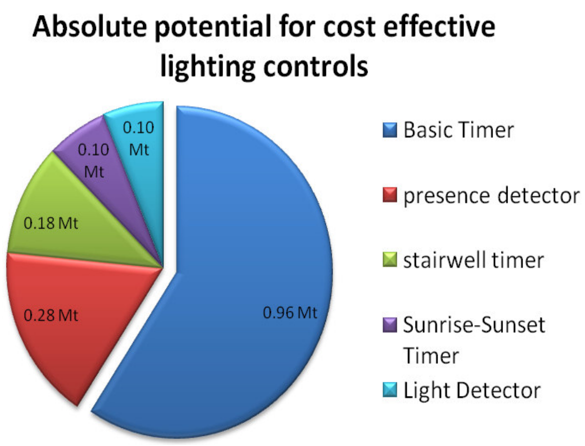
LEDs
Light emitting diodes are considered a niche market at present but the technology is expected to develop over the next decade to become increasingly important by 2022. Costs are at present prohibitive to mass market uptake but the US Department of the Environment suggests that LED prices will halve over each five-year span for the next ten years[47].

Market penetration
Data from the market transformation programme has been used to estimate market penetration levels since 2002. The estimate of the total penetration is given here and differs significantly from estimates provided by BRE in previous work for CCC (see appendix). Payback periods for typical light replacement technologies were also calculated and compared with the literature data.

	Triphosphor (T8)	Metal halide	CFLs (for GLS)	HF ballast	IRC halogen
MTP estimate of total market penetration (2008)	20.4%	0.26%	25.8%	19.6%	0%
CE fraction	15%	100%	52%	22%	40%
Payback CE (yrs)	1.5	2.3	1.4	1.5	1.3
Payback NCE (yrs)	5.7	None	None	None	None

1.1.2 Lighting Controls

Lighting controls were identified to have 1.62MtCO2 per annum of cost effective potential for CO2 saving in 2007.
There is little information about the penetration of lighting controls since the Sheffield Hallam work available in the literature. BRE estimated in a 2% penetration of 2002 technical potential by 2007.



Payback periods
Payback periods calculated from the BRE data produced unrealistically short payback periods and were therefore revised during the consultation process and literature review. Indications from the Carbon Trust suggest an occupancy detector (with built in daylight sensor), would typically cost around £200 (plus VAT) to install using a contractor and could result in a five year payback[48].
Information from the USA indicates shorter paybacks of 1-3 years

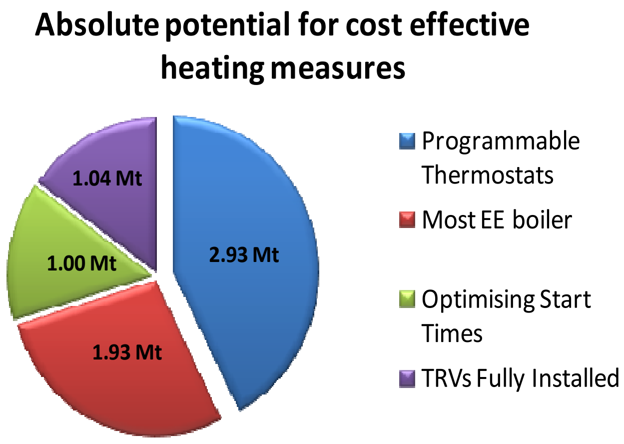
N.B. The realization of the potential savings stated is heavily dependent on the use and programming of the installed controls.

[47] Navigant Consulting Inc. 'Energy Savings Potential of Solid State Lighting in General Illumination Applications', U.S. Department of Energy, 2003.
[48] Assumes at least 500 kWh/year of electricity is saved (based on 7.9p/kWh, including CCL)

1.1.3 Heating – boilers and controls

Heating and the associated controls represent two thirds of the 2007 cost-effective potential for CO_2 savings in the non-domestic sector (c.8.67MtCO_2 per annum).

Much of this potential is in replacement boilers which are currently covered by guidance associated with part L, Non-Domestic Heating, Cooling and Ventilation Compliance Guide. DCLG, May 2006[49]. This specifies a minimum efficiency for the system (see appendix).



If the seasonal efficiency is less than the minimum, credits can also be gained for controls (such as TRVs (1% point), room thermostats (0.5% point) and optimising start times (2% points). The minimum requirement for controls, however, is simply an on/off control by zone for buildings greater than 150m^2 and a time clock. Beyond this, controls are discretionary and are assumed to have payback periods in the range of 2-5 years for cost-effective installations.

1.1.4 Air conditioning

Air conditioning was assumed to have a cost effective technical potential of 0.28Mt of CO_2 saving in 2007. This, however, is a growing sector with an annual sales growth of 4% in the period 2004 to 2006. Overall the number of installed air-conditioning systems is expected to increase by about 80% by 2020 with a 60% increase in the sector energy consumption[50].

There has been some improvement in energy efficiency in recent years with market penetration of Class A sub 12kW packaged products up from c.3.5% in 2002 to c.26% in 2006. Class G products have also been eliminated (c.17% of market in 2002).

Payback

BRE considered an energy efficient air conditioning system to involve "more appropriate sizing and design and more efficient components" and assumed the apparent cost of such a system to be zero. This can be explained if the technology is assumed to be mandated, however, the energy efficiency ratio required for compliance with part L building regulations is currently significantly below the best available technology[51]. The Market Transformation Programme has identified that increasing the EER to the best technology available worldwide could lead to a CO_2 saving of over 50%.

A cost penalty is expected in purchasing more efficient products, however, due to the range of capital costs dependent on the system requirements (up to two orders of magnitude), there is insufficient data to define this additional cost. AC systems typically operate under part load and are designed with safety factors and some flexibility in mind and good system design may be able reduce the size requirement and hence capital cost to trade off the penalty. This design, however, requires knowledge and skill and comes at a premium.

Overlap

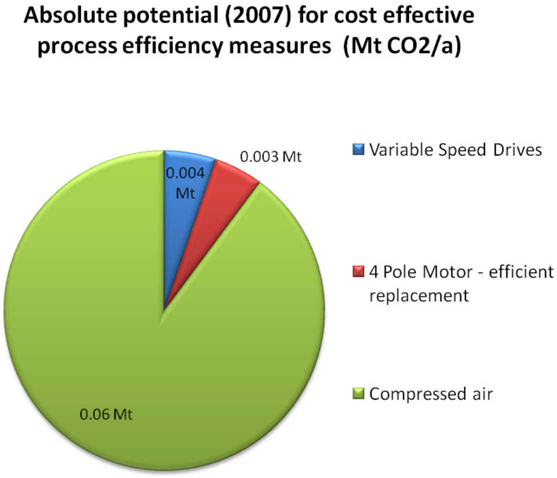
There is some overlap between motors and air conditioning. Motors driving compressors and fans account for up to 95% of energy consumed by AC products[52]

[49] Guidance on showing compliance with paragraph 41 in Part L2B
[50] Policy Brief: Improving the energy performance of air conditioning products, Defra (2008). This does not take into account any predicted climatic changes.
[51] E.g for mini split-air conditioners, 2.4 compared to the best available of c.5.0
[52] MTP policy brief

1.1.5 Process Efficiency

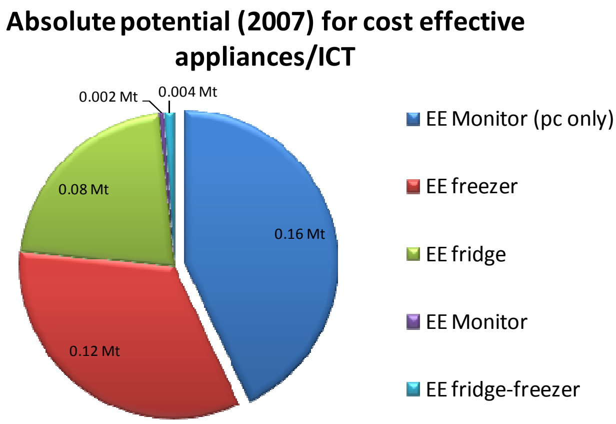
The absolute technical potential for process efficiency in the non-domestic sector is small compared to the other measures discussed here. The total cost-effective potential of c.0.067Mt CO2 per annum is also dwarfed by the non-cost effective potential (c.0.19Mt CO2 per annum).

Despite this, some uptake has been observed. The Building Regulations have a minimum energy performance standard for ventilation systems in buildings ('Specific Fan Power') and consequently have stimulated a high uptake of variable speed drives in these applications[53].



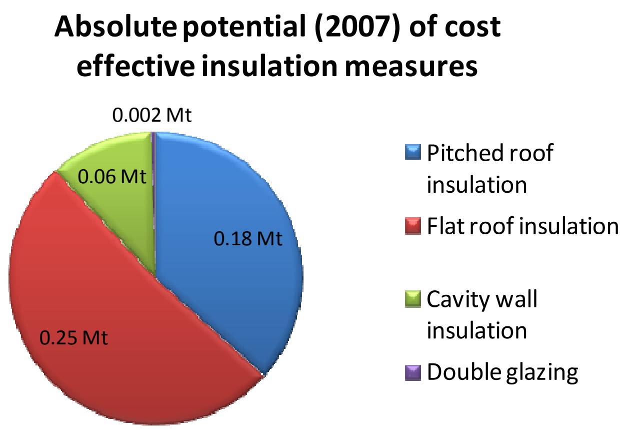
1.1.6 Equipment

The total cost effective potential for CO_2 savings from energy efficient equipment is c.0.36 Mt per annum). Monitors represent the bulk of the potential. BRE previously modelled technology replacements replacing standard CRT (cathode ray tube) monitors with flat screen LCD (liquid crystal diode) monitors or Organic Light Emitting Diode (OLED) monitors.
The market transformation programme indicates that market penetration of 84% has already been achieved with LCDs.



1.1.7 Insulation

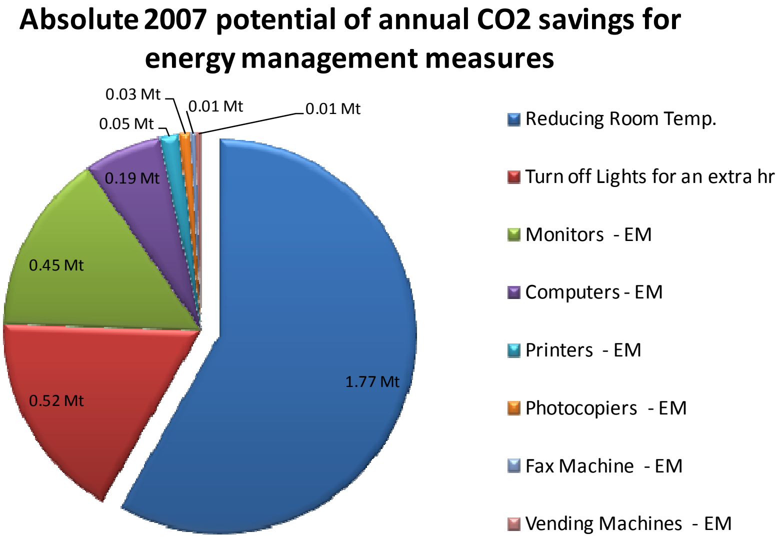
The technical potential for insulation measures in the non-domestic sector was identified as 2.43MtCO_2 per annum. The majority of this, however is non-cost effective with only 0.49Mt of cost-effective potential remaining.
Roof insulation dominates the latter potential. According to the Carbon Trust, it is not usually economical to add flat roof insulation unless already carrying out repair work[54]. This supports the long payback periods estimated using CCC data in this study.



[53] Policy Brief: Improving the energy performance of motor-driven systems, Defra (2008)
[54] Building fabric: Energy saving techniques to improve the efficiency of building structures, Carbon Trust (2007)

1.1.8 Energy management

The majority of energy management potential appears to be in reducing room temperature, followed by turning lights off for an extra hour. In both cases interactions exist with the controls measures which facilitate this behavior.



1.2 Non-cost effective measures

Simple payback periods were calculated for measures defined within N-DEEM as non-cost effective. In the majority of cases, measures did not pay for themselves within the lifetime of the kit concerned. There were two notable exceptions to this rule, replacements for 26mm halophosphate fluorescents and low-loss ballasts. The latter were aided by predicted increases in energy prices over the study period.

2 NON-DOMESTIC DECISION MAKERS

2.1 User breakdown

In this study, decision makers have been disaggregated into the following types: public sector, large non-industrial organisations, SMEs and commercial landlords. Each category has different motivational drivers, practical constraints and barriers and thus is subject to distinct existing policies.

No published information was found to accurately explain the split between landlords and tenants and owner-occupier in the non-domestic sector. Anecdotal evidence from consultees suggests that c.50% of offices are owner-occupied. The following split was therefore used in this study[55]:

	Technical Potential (% of total)	Of which owner occupied
Public sector	3-20% (dependent on technology)	75%
Large businesses	18-50%	50%
SMEs	18-50%	

Whilst SMEs represent over 90% of the organizations in the UK their technical potential is similar to that of large businesses.

2.2 Decision-making frequency

2.2.1 Replacement technologies

The decision-making frequency for replacement technologies is defined, as in the domestic sector, by the lifetime of the incumbent technology. Heating controls are included in this bracket with the decision-making frequency defined by the lifetime of the boiler. Historically little uptake of controls has occurred independently of boiler replacement.

Technologies included: Boilers, replacement lights, appliances, air conditioning, process efficiency measures, heating controls

2.2.2 Discretionary technologies

Technologies included: Lighting controls, insulation, behavioural measures

2.2.3 Rate of refurbishment and tenancy lengths

Refurbishment of the existing non-domestic stock provides an ideal opportunity for the installation of energy efficiency measures, without disrupting business productivity and without the complications of landlord-tenant contracts in place limiting modifications to a property. In this analysis, refurbishment and tenant changes are taken as trigger points which govern the number of people coming forward to make a decision each year.

Comprehensive statistics on refurbishment rates do not appear to be available, data is confined to specific sub-divisions of sectors (e.g. public sports centres) and therefore general rules of thumb must be applied. Assumptions include a major refurbishment of 3%[56] of the stock each year and a small-moderate refurbishment every 15 years.

In addition, it can be assumed that some refurbishment may occur at the point of any change in tenancy. The length of tenancy typically varies according to the desirability of the property and type of tenant. Public sector organisations, for example, have an average lease period of

[55] Previous work by CCC subdivided energy saving potential into those businesses that were likely to be subject to the Carbon Reduction Commitment in future, and the remainder.

[56] Bill Bordass Associates, personal communication, (2% Carbon Trust, personal communication)

c.13 years compared to the average office lease of 7 years[57]. The final fit-out is typically the responsibility of the tenant with the owner/landlord responsible for more major alterations. The general trend observed by the British Property Federation for shorter tenancies, may act as a barrier as businesses require paybacks to occur within the lease period.

The major refurbishment (c.3%), small-moderate refurbishment (c.7%) and tenancy changes (c.14-20%) provide us with three scenarios for decision makers coming forward. The latter scenario could be forced (e.g. by requiring an energy plan with every tenancy change). In addition the forthcoming Carbon Reduction Commitment (CRC) requires annual reporting of CO_2 emissions of those involved. In this study it is simply assumed that the CRC increases the number of decision-makers to 100% of the population affected by the policy.

2.3 Historical data

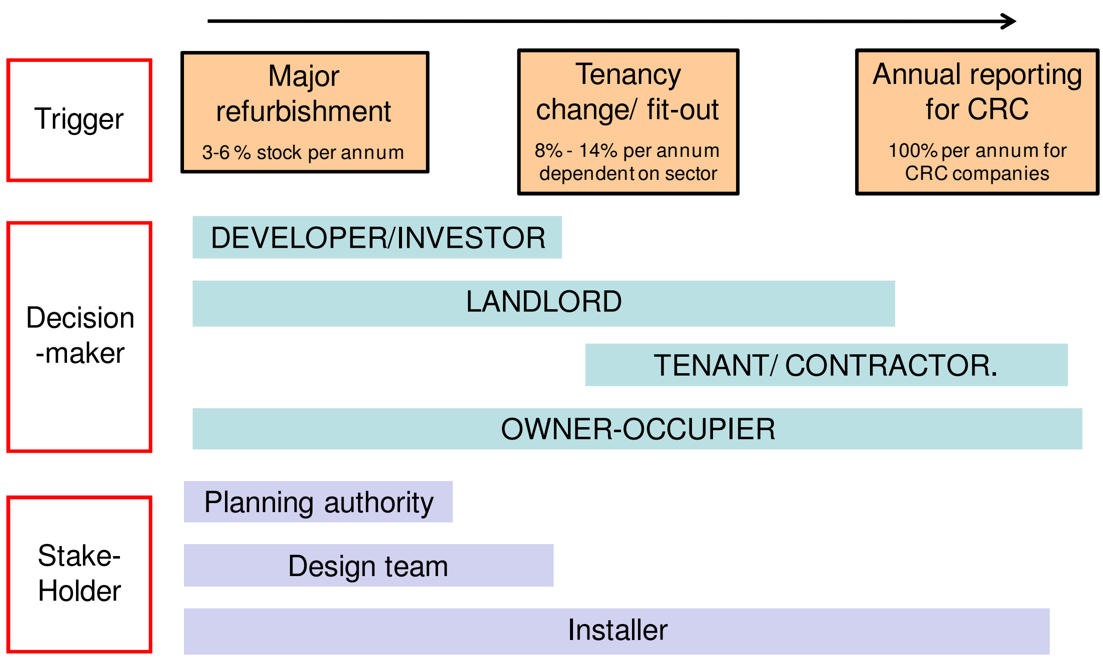
The Carbon Trust has delivered direct advice products to 24% of each of the large (greater than £5million) medium (£500k-£500m) and small (£50k-£500k) segments over the eight years since its inception in 2001.

2.4 Decision makers/Stakeholders

The non-domestic stock has the added complication of a much wider range of potential decision makers, and, in larger organisations, there is the prospect of a complex decision tree which may involve some or all of the following: the board, finance director, facilities manager, staff, a commercial landlord, external building operator/ services manager, sub-contractors, developers and capital providers. Decisions in commercial property are made increasingly complex by contracts that exist between these stakeholder groups which may restrict or demotivate actions of a particular group.

It is important to understand this decision making process to properly understand who is involved in assessing the options at each stage, what motivational drivers do they possess and therefore how willing/able are they to pay for an energy efficiency measure.
The following diagram shows the potential decision-makers present at each trigger point

Trigger points, stakeholders and decision makers for discretionary technologies



[57] British Property Federation

2.4.1 Landlords

Landlords/developers and their investors are likely to be responsible for the design and implementation of major refurbishment of a property, with the precise end-user frequently yet to be determined. The final finish or fit-out is usually the responsibility of the tenant, but under traditional commercial leases is subject to approval by the landlord[58]. Clauses in the lease agreement may act to restrict tenants from carrying out significant energy efficiency alterations themselves by requiring them to return the building to a particular state.

Landlords and developers therefore represent a key decision-maker in the area of energy efficiency, particularly for building fabric measures and major building service alterations.

Survey work carried out on behalf of the EST, indicated that commercial landlord decisions are primarily influenced by:

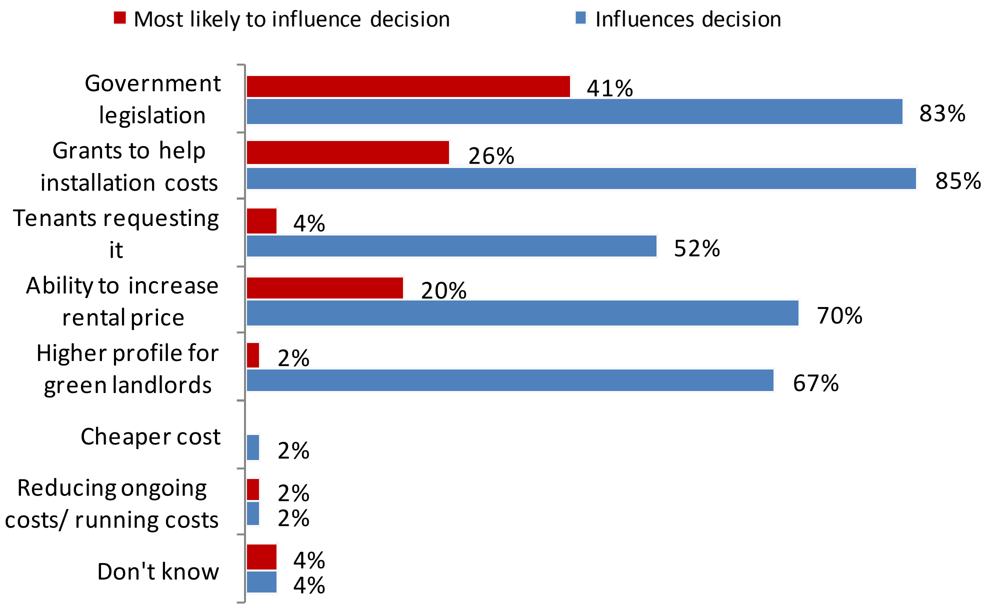
- Government legislation/ regulation
- The ability to increase the rental price/ resale value

They are also highly sensitive to capital cost as they are unlikely to reap the benefits of reduced ongoing running costs. Other factors influencing their decision to a lesser extent include tenants requesting measures and the increase in profile associated with being a green landlord.

There is no apparent evidence for a premium at present for energy efficient properties in the UK, although some developers have communicated an apparent decrease in the period of time a property is on the market[59]. This is supported by the survey data, 57% of commercial landlords, agreed strongly with the statement that tenants are not bothered whether the properties they rent are energy efficient (23% higher than their domestic counterparts).

Commercial landlords also demonstrated a strong sense of inertia with 50% agreement with the statement "there is no point in doing anything when governments around the world don't do enough to save energy themselves".

Most important factors likely to influence installation of energy efficiency measures for landlords



Data source: Energy Saving Trust and Continental Research (2005)

[58] RICS
[59] Personal communication, Carbon Trust.

2.4.2 Tenants/ owner-occupiers

Potential drivers for installing energy efficiency measures for the tenant or owner-occupier include:

- Financial savings
- Corporate social responsibility/ green PR
- User comfort
- Environmentally friendly products/ selling point

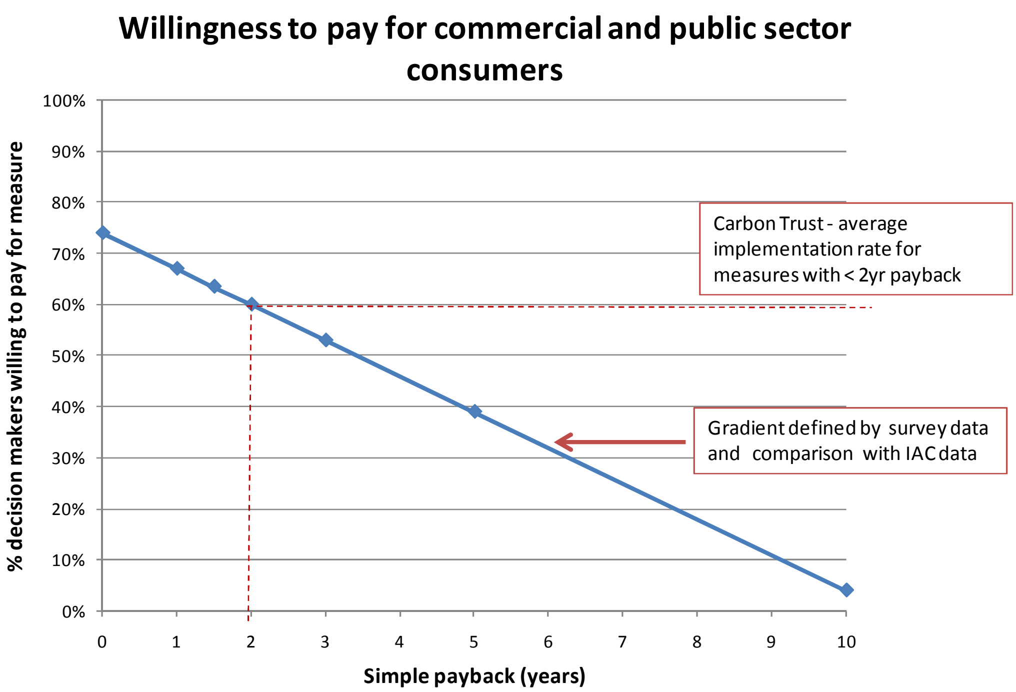
The Board, finance director, facilities manager, staff, external building operator/ services manager and sub-contractors might all be involved in the decision-making process, dependent on the scale and type of measure under consideration.

3 WILLINGNESS TO PAY

The willingness of the non-domestic sector to pay for energy efficiency measures was determined from survey work, literature review and consultation with Carbon Trust data[60].
The Carbon Trust Close-Out database is a record of c. 40,000 site surveys, carbon management programmes and similar work that Carbon Trust has conducted since its inception in 2001.

The data shows 60-70% implementation rate for paybacks of less than 2 years (albeit with a lot of decision support from Carbon Trust)[61]. There are no indications of any significant differences between large and small commercial companies, or between the public and private sector and hence no differences have been assumed in this work in the current population.

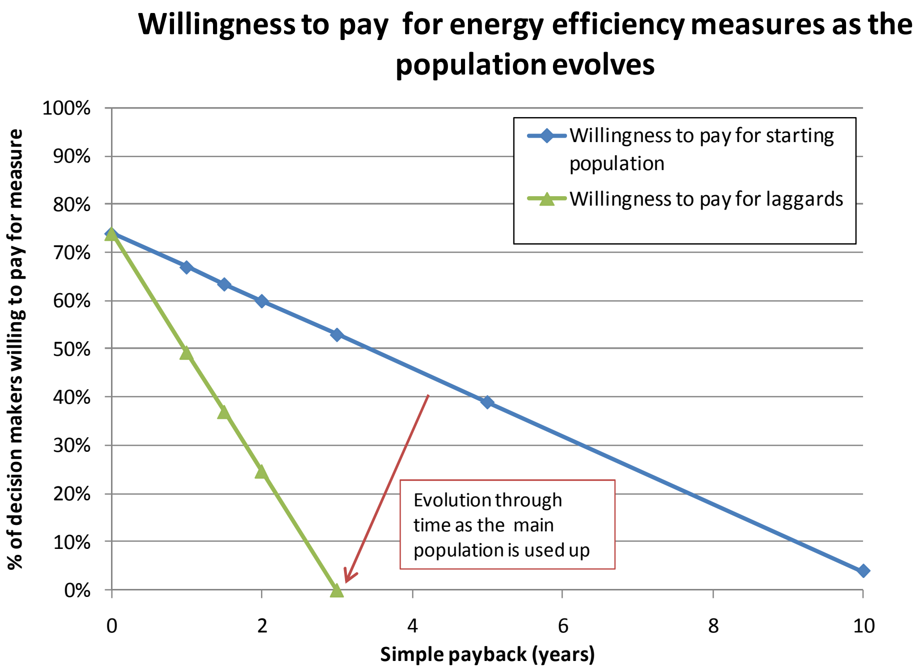
Survey data, collected by Element Energy from commercial landlords and business/facilities managers was used to generate the gradient in the graph below. This graph also compares well with real industrial data on willingness to pay from the Industrial Assessment Centre Database in the United States[62].



3.1 Laggards and price elasticity in the commercial sector

As previously mentioned the same initial willingness to pay graph is used for all groups. The percentage of the population behaving as laggard is, however, assumed to be dependent on consumer type. The graph below indicates how the willingness to pay is assumed to evolve through time in the non-domestic sector.

[60] The model differentiates between WTP and the prior step, which is interest in taking action. In this way, selection bias is avoided because the data is used only to describe the behaviour of stakeholders that already have taken a decision to be proactive and consider measures.
[61] Carbon Trust, personal communication
[62] IAC Database, U.S. Department of Energy, http://www.iac.rutgers.edu/database/



	Large businesses	SMEs	Public sector	Landlords
% laggards in population	18%	38%	0%	50%

The percentage of laggards in each group was defined by reviewing the following sources of information:

- EST Landlords Quantitative Research – Commercial landlord data
- npower Business Energy Index (BEI) Winter 2007—2008[63]

The latter represents an annual telephone survey of 100 UK SMEs and 100 major energy users (MEUs) regarding energy costs, efficiency measures and attitudes to energy policy. Major energy users included 23% from the public sector and just over 50% from the manufacturing industry.

The following results originated from this survey work:

SMEs

In 2008 energy costs constituted on average c.6% of an SME's total operating costs, (compared to c.11% in winter 2006) with the majority having costs of less than 5%. These low percentages can help to explain why 46% of SMEs do not currently measure their energy efficiency levels at all. In contrast, 97% of MEUs measured their energy efficiency. The laggard group can arguably be represented by the following:

- 46% who do not measure their energy efficiency
- 41% who perceive no change in profitability in response to rising energy prices
- 38 % who have taken no steps at all to improve their energy efficiency in the last year or so (even by requesting information)
- 19% identified not to support the UK government's commitment to reducing carbon emissions.

The average value of 38% is chosen in the reference scenario of this study.

In contrast, there are also significant positive signals from this work. 50% of SMEs would be prepared to pay a premium for energy that reduces CO2 emissions (though typically only up to 5%).

[63] npower Business Energy Index (BEI)– Winter 2007—2008

Landlords

In the EST Landlords Quantitative Research carried out in 2005, 43% of landlords did not agree with the statement "When I am buying properties to let I always consider how energy efficient it is" and 65% did not agree that they had a better resell value. 72% of landlords also did not agree that their tenants were bothered about energy efficiency in the property. These results point to a large percentage of laggards in the commercial landlord population. There is likely, however to have been some improvement since this survey work was carried out. In 2008, 41%[64] of SME tenants stated in that their landlords had taken some steps to improve the energy efficiency of their building.

MEUs

The BEI noted that 69% of MEUs employ staff full time for the purposes of energy management and 47% see potential for new commercial opportunities as a result of decreasing their carbon footprint. 62% of MEUS have also changed their equipment in some way in response to rising energy and 70% have changed their heating or lighting.

Public sector

The public sector area assumed to be subject to additional drivers compared to commercial enterprises. It is therefore assumed for simplicity that their behaviour does not change as the remaining population reduces.

[64] BEI

4 BARRIERS

4.1 Non –domestic demand side barriers

The following barriers were discussed in the domestic sector and are also applicable to the non-domestic sector:

- Inertia
- Lack of / incorrect information
- Financial barriers
- Hidden costs
- Disruption
- Split incentives
- Commissioning/handover
- Ongoing management time

The non-domestic model is similarly designed such that a lack of information and unwillingness to disrupt business and inertia restrict the number of people coming forward to make a decision in a given year. Financial barriers (e.g. insufficient payback periods), hidden costs and ongoing management costs are then taken into account when a decision-maker decides whether to implement the measure. In addition inertia in the population is also represented by laggards in the population, with a lower willingness to adopt a measure with a given payback.

It is hard to represent split incentives between external parties in an uptake model, however, this is currently implemented by assuming a larger proportion of the landlord/tenant population are laggards. This issue is extremely important and is discussed further here.

4.1.1 Poorly aligned/split incentives

Split incentives in the non-domestic sector present a complex issue; not only can institutions/businesses have misalignments within a company (e.g. a finance director may not see the benefit in his budget of an energy saving, but is required to commit the capital by the facilities manager), but there are also external split incentives between the user and commercial landlord.

Lease arrangements between tenant and landlord often prevent mutually beneficial upgrading and for added complication, unlike the domestic sector it is common to have multiple tenants under the same private landlord in the same building. Installing energy saving measures may require buy-in from all tenants concerned, although smaller tenants may be influenced by their larger counterparts. In terms of behavioural measures, individual companies may not be sub-metered and may therefore not see the full benefit of their actions. In addition, each tenant may have different requirements (e.g. in terms of operational hours) which may result in a “default to on” setting for the building as a whole. In this situation there is even less clarity over who is responsible for identifying and progressing energy improvements in each building.

Refurbishments have previously been noted as potential trigger points for installation of energy efficiency measures. Here there are also clearly split incentives. Refurbishments are often driven by time, superficial image and maximising rents. If installing a measure does not increase the rental value of a property for a landlord, measures are unlikely to be implemented. In addition, valuations may favour the addition of technology and increase energy consumption (e.g. the installation of air conditioning into a naturally ventilated property).

4.1.2 Optimisation of systems

Design of more appropriately sized systems during major refurbishment may suffer from a range of issues besides split incentives. These include:

- Flexibility requirements in future and current use of the building (particularly for multi-occupant buildings)
- Liability for the engineering design team/architect over performance of the system (leading to generous safety factors)
- Lack of communication between end-user, purchaser (e.g. landlord) and design team

4.1.3 Commissioning/handover and use

This barrier represents a potential loss of CO2/energy savings through poor installation and handover to the user. It may also act to discourage the user from installing further measures as prior saving expectations were not realised. Complex systems which require good management to maintain represent a particular problem, both in terms of cost of time and skills to the company concerned and the understanding of the system may be lost with staff or tenant changes.

4.2 Variation in barriers by consumer type

Demand side barriers have been recognised to vary according to user type in the non-domestic sector. Work by the Carbon Trust, for example, has demonstrated that SMEs are particularly concerned with transaction costs (e.g. additional time required to implement the project) and ongoing management requirements and have a tendency to place potential energy saving measures as low on the priority list. SMEs, typically suffer less, however, from complex decision processes within the organisation (an internal split incentive). This can be represented by differences in the value of hidden and missing costs for the end user groups, differences in the rate of people coming forward to make a decision and in their willingness to pay and by differentiation in the number of laggards. Differences in hidden and missing cost values were not modelled in the reference scenario.

4.3 Supply side barriers

Supply side barriers are not examined in detail in the commercial sector. Many of the products (such as air conditioning, IT) are internationally traded goods and as such are likely to be subject to global rather than UK constraints. Replacement of technologies is restricted by the lifetime of the incumbent kit where appropriate.

5 CURRENT AND PLANNED POLICY

5.1 Building Regulations (2006)

Current

The 2000 Building Regulations were revised in 2006 in order to meet with the requirements of the EU Energy Performance of Buildings Directive.

Part L2B of the building regulations applies to consequential improvements in buildings over 1000 m^2 where the proposed work consists of an extension, the initial provision of any fixed building services such as heating, ventilation or air handling or an increase to the installed capacity of any fixed building service. The whole building is required to comply with Part L if technically, functionally and economically feasible[65].

The building regulations therefore ensure that there is some degree of mandation with regards to the replacement of boilers, air conditioning system and glazing. These technologies are therefore modelled as mandatory where cost effective in the approach. In addition this regulation should motivate the more economically feasible building fabric improvements at the point of major refurbishment.

Future

This legislation is again due for revision in 2010 and an overall target for Part L of a 25% reduction in CO2 over the 2006 revision is currently being considered. This is proposed to be introduced at an aggregated level rather than at a flat rate (i.e. not all buildings will be required to meet the same target) to allow for more cost effective savings.

Note that regulations can also act as a disincentive, as people try to meet the minimum requirements only.

5.2 Display Energy Certificates and Energy Performance Certificates

From October 2008 Energy Performance Certificates (EPCs) are required when any building is completed, sold, rented, and sometimes after refurbishment work. It must be completed by an accredited energy assessor. This provides some indication to the landlord, tenant or owner-occupier as to the performance of their heating and ventilation services, insulation, building construction and type of fuel usage. The recommendation report that is included with an EPC provides indication of measures with:

- a short term payback – less than three years
- a medium term payback – between three and seven years
- a long term payback – greater than seven years
- other recommendations (based on the energy assessor’s knowledge).

Energy Performance Certificates could therefore act to motivate or trigger energy efficiency improvements at the point of tenancy change.

Display Energy Certificates (DECs) came into effect in October 2008 and are only required for public sector buildings with a total useful floor area over 1000m^2. These must be renewed every year and include the following which are not considered under the EPC:

- Fixed building services not covered by building energy regulations in the base building and added during the occupier’s fit-out (e.g. lifts, outdoor lighting, communications, machine room cooling)

[65] Economic feasibility requires a simple payback not exceeding 15 years. In the case of extensions, the consequential improvements must cost not less than 10% of the principal works.
Where building services are being installed or upgraded, two sets of improvements are required; improving the areas of the building covered by the services and improving the rest of the building fabric. Costs incurred in the first part do not count towards the economic feasibility of the latter building fabric improvements.

- Equipment, appliances and special services (e.g. office equipment, electronics, catering, process equipment and server rooms)

DECs therefore describe the building as it is actually used and offer a much more accurate and applicable source of information for the user than their EPC counterparts. The annual requirement means that users receive feedback on the impacts of any improvement or changes they may have made.

5.3 CARBON REDUCTION COMMITMENT

Who is in?
Organisations with greater than 3000MWh electricity consumption MUST report every few years to administrator
Organisations with greater than 6000MWh electricity consumption MUST register and participate in the scheme (excluding emissions covered in CCAs, the EU ETS and transport).

Potential impacts:

- **Raising awareness** (therefore increasing the number of people coming forward to make a decision each year)
- **Some alignment of external incentives** between stakeholders (through liability of some landlords in multi-let properties)
- **Some alignment of internal incentives** by bringing decisions on energy efficiency measures higher up the decision tree (some alignment of internal incentives)
- **Non financial PR incentive to perform**. Some exposure/positive or negative press for best and worst companies

Timescales

- Sales of allowances begin in April 2011
- Little impact is expected prior to 2013 (according to consultees) as scheme gets off the ground.

Penalties and compliance
Offences punishable by a penalty or fine will be:

- failing to participate/supply data or failure to register or surrender allowances
- supplying false or misleading information

Companies who fail to comply/report incorrectly will be named and shamed. It will be a criminal offence to knowingly deceive the administrator, punishable by a fine of up to £50,000 or imprisonment for up to 3 years.

Potential failings:

- The CRC represents a small percentage of energy costs which already represent a small fraction of business costs. This may lead to policy being seen as a tax on energy, to be paid rather than motivating action.
- 75% of major energy users expressed concern in the Business Energy Index that the combination of policies including the CCL, EU ETS and CRC placed an undue burden on UK businesses. 71% felt it would make UK business uncompetitive.

CRC is modelled here to increase decision making frequency to 100% for companies involved. Cost implications of CRC are currently low (£12/t allowance).

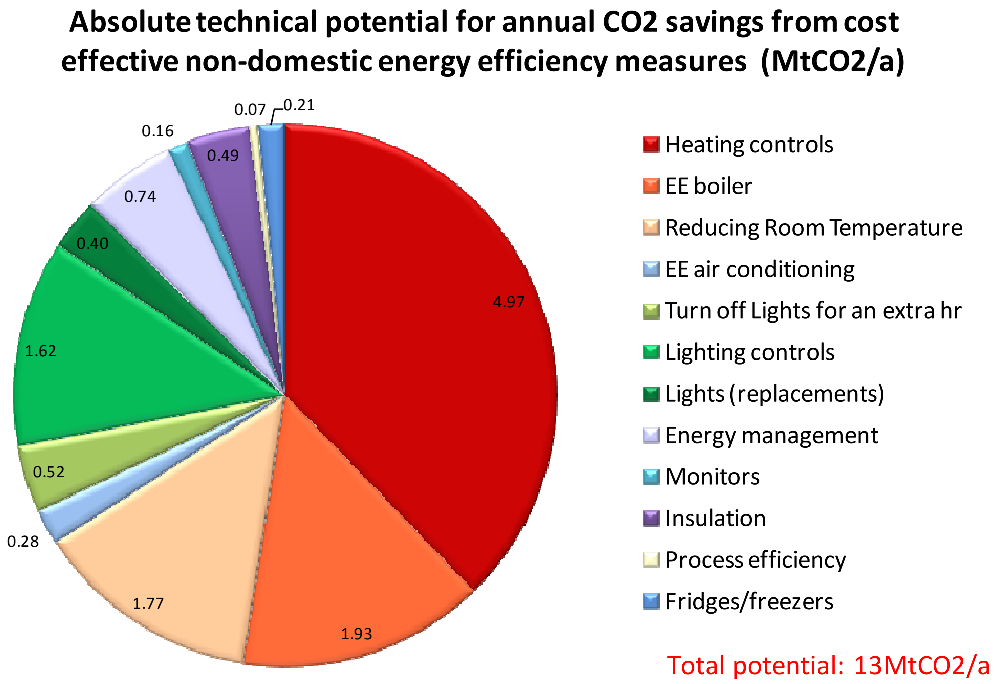
5.4 Other policies

Other currently active policies include the Enhanced Capital Allowances, loans to SMEs through the Carbon Trust and Scotland's business advisor network.

6 RESULTS

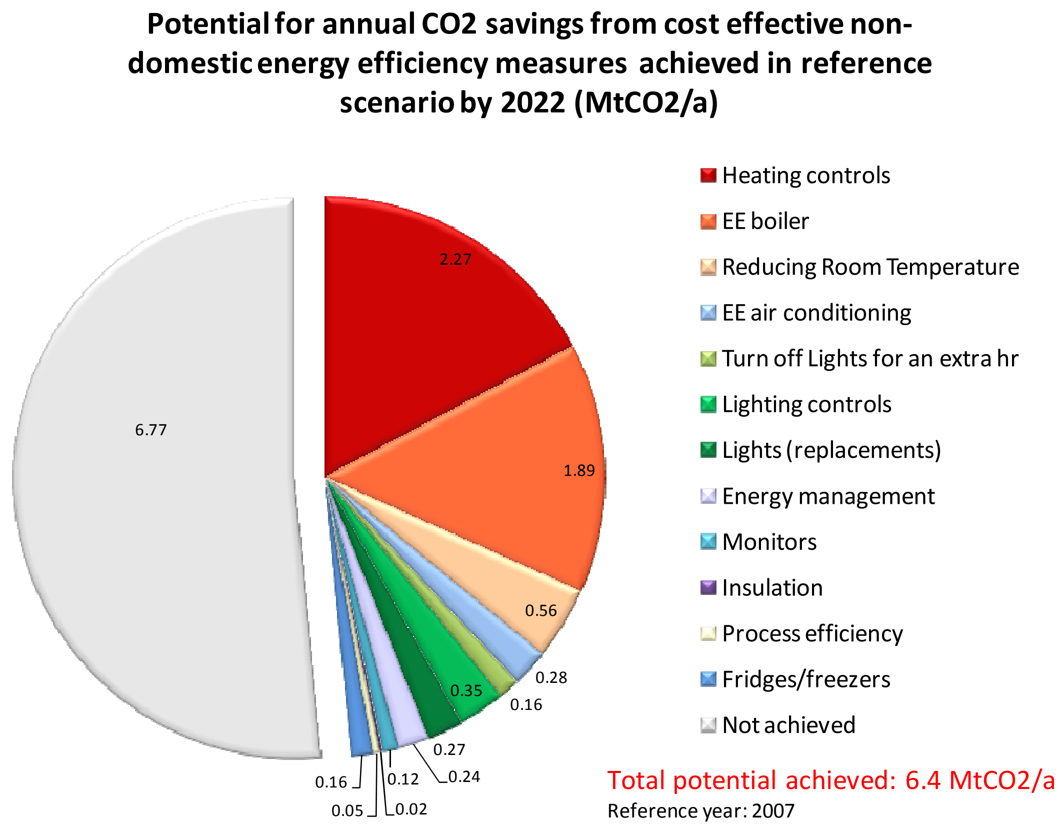
REFERENCE SCENARIO OVERVIEW

The following pie charts compare the absolute technical potential for annual CO_2 savings from cost effective energy efficiency measures in 2007 with the savings achieved under the reference scenario by the end of 2022.



An additional 4MtCO2 of technical potential is assumed to be not cost effective.

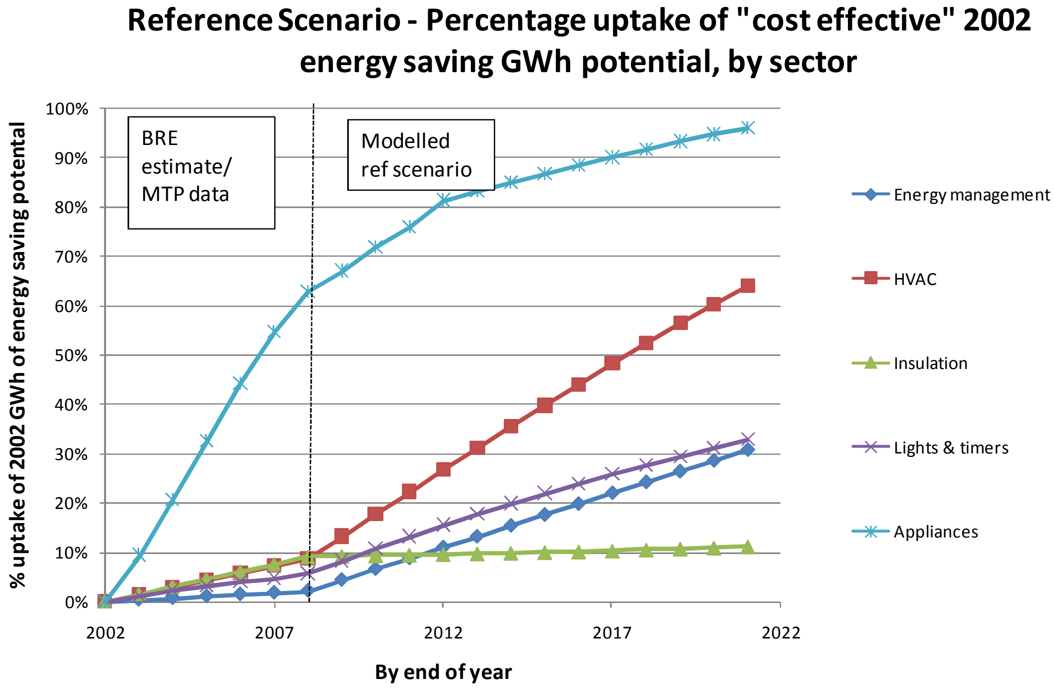
	2007 technical potential	Reference case – Savings realised by end 2022 ($MtCO_2/yr$)
Heating controls	4.97	2.27
EE boiler	1.93	1.89
Reducing room temperature	1.77	0.56
EE air conditioning	0.28	0.28
Turn lights off for an extra hr	0.52	0.16
Lighting controls	1.62	0.35
Lights (replacements)	0.40	0.27
Energy management	0.74	0.24
Monitors	0.16	0.12
Insulation	0.49	0.02
Process efficiency	0.07	0.05
Fridges/ freezers	0.21	0.16



As for the domestic sector, the reference scenario includes only those policies that were firmly funded and committed prior to the Energy White Paper and as such does not include the EPCs, DECs, or the Carbon Reduction Commitment discussed in the previous section. All of these can be expected to increase the overall decision-making frequency of the sector. This reference scenario achieves roughly half the cost-effective potential by the end of 2022.

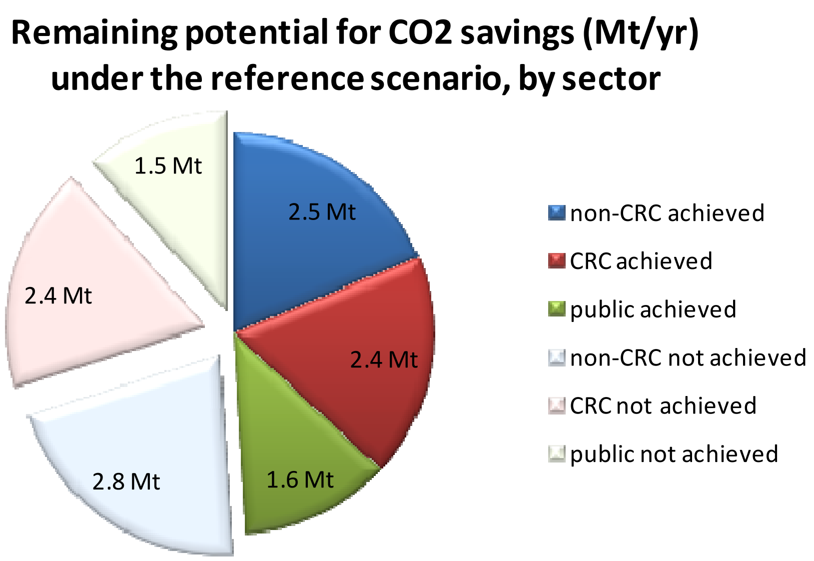
Energy efficient boilers perform well in the reference scenario, achieving their technical potential due to the regulations already in place. Appliances represent a small fraction of the potential but again perform well, primarily due to the uptake of energy efficient monitors.

This can be contrasted with the adoption of heating controls which achieve less than half of their potential. Lighting controls similarly perform poorly. Minimal uptake of insulation measures is predicted based on the payback periods calculated in this study.



By sector

The overall technical potential and uptake over the period to 2022 can be subdivided by sector (public, small to medium enterprises and large organisations) to examine which segments, if any are under-performing and require policy support. Large organisations here are defined as those that will be subject to the Carbon Reduction Commitment, although this policy is not included in the reference scenario.
The following pie chart shows the roughly even split of remaining potential savings in 2022 under the reference scenario between sectors. There is a difference in achievement between the groups with small to medium (non-CRC) companies achieving the lowest fraction of their potential.



6.1 Lighting

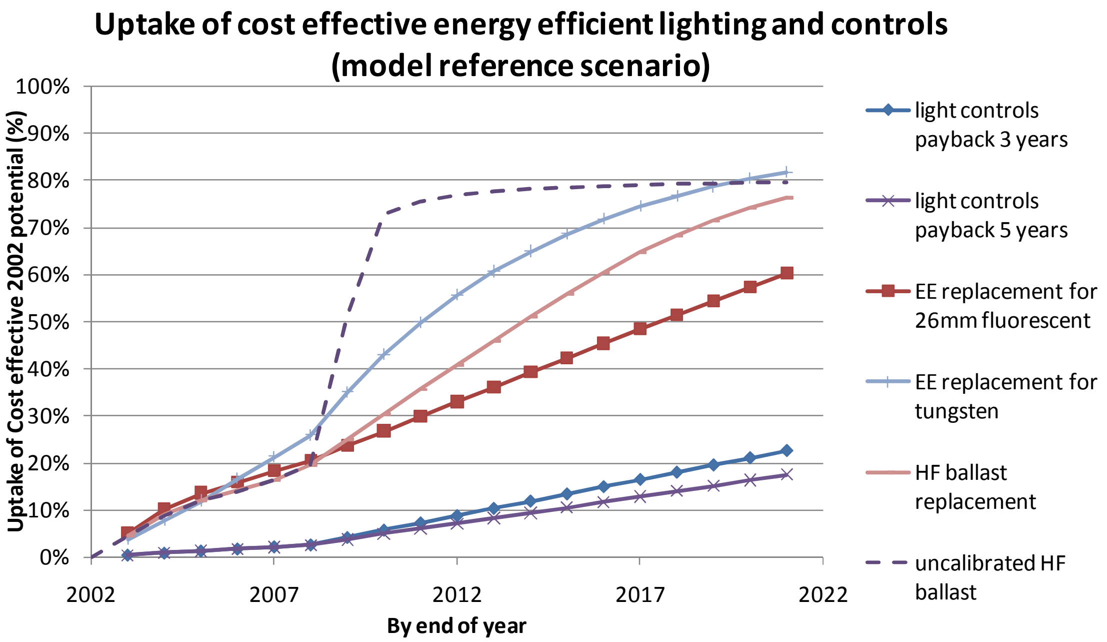
The potential for energy efficient lighting is best understood when subdivided into replacement bulbs/ballasts and lighting controls.

Reference scenario - Controls

Controls are assumed to be discretionary and considered at the point of renovation in the reference scenario (i.e. no replacement decision). The low frequency of trigger points severely restricts uptake and uptake of 2002 potential only reaches c.20% by 2022. The range of paybacks quoted by the Carbon Trust[66] leads to a small but noticeable difference in uptake over the period.

Replacement lights

We initially assume that all consumers consider EE replacement for a bulb/ballast when the incumbent light fails. The cost effective payback is typically very short and would predict rapid uptake without calibration (dotted line on following graph).



Calibration was required to reflect historical uptake rates (2002-2008) collated from the Market Transformation Programme. There are several reasons which could explain the necessity for this calibration factor:

1. **Inertia** - consumer automatically buys the same product as before (this is a known entity, may already be on order list/have some in stock) without considering alternatives. 100% decision making frequency at end of useful life is an overestimate.
2. **Aesthetics** - Consumer considers product but decides against it for perceived aesthetic/ergonomic reasons (e.g. colour rendering, warm up time)
3. **Compatibility** - Product may not be compatible with existing fittings. Payback period and calibration therefore does not accurately reflect cost and hassle of replacing fittings/fixtures.
4. **Lack of awareness of benefits**

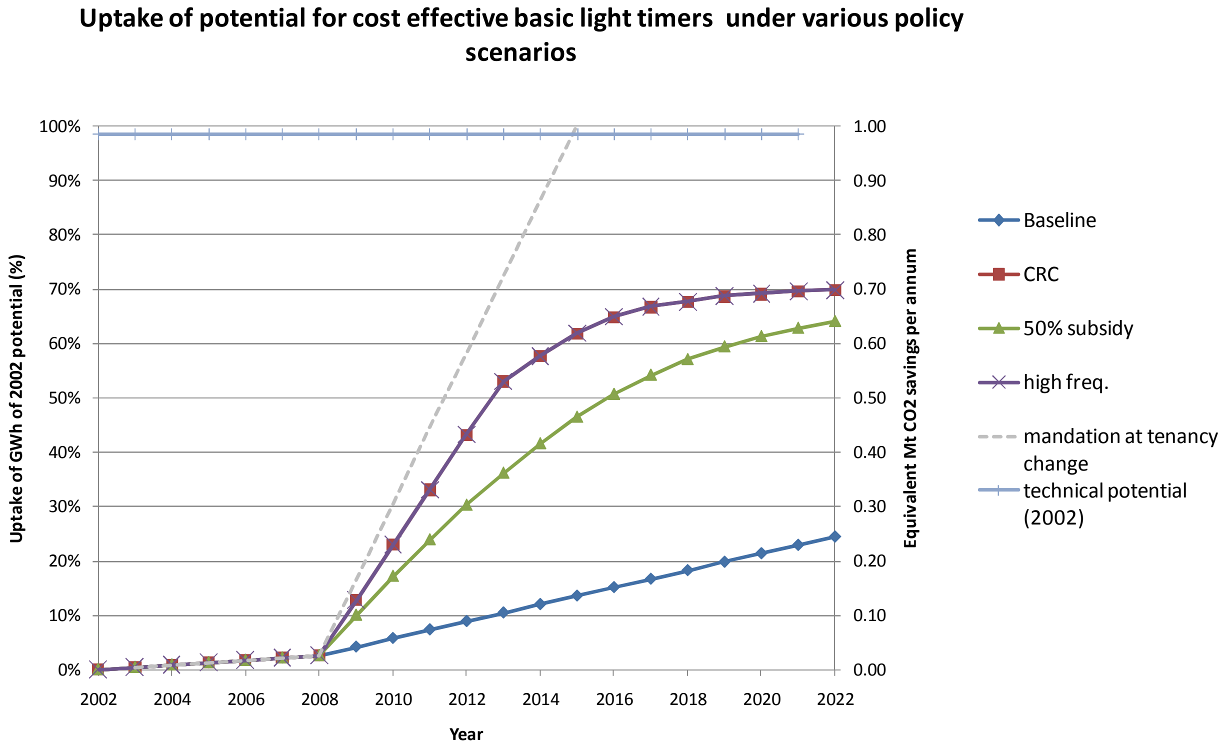
The latter point has been mentioned in particular with respect to metal halides and IRC halogen bulbs, which are poorly modelled even with the calibration factor.

[66] We use a payback when all costs are considered of 3-5 years (Carbon Trust) rather than the short paybacks calculated from the BRE data based upon the cost of hardware

Policy - Controls

Effective legislation on lighting controls is difficult (i.e. forcing their installation and use). Intervention may be more effectively achieved through increasing decision making frequency by targeting tenancy changes and annual reporting points (e.g. for the CRC or DECs). The graph below suggests that this is likely to have a more significant impact than offering a 50% capital subsidy for the hardware for installation. The hidden costs for the measure ensure that such a subsidy does not generate the full potential.

Mandation of installation of timers on tenancy change would lead to 100% saturation by 2015 at the earliest. Whether all of these timers would be used is another matter. The difference in use and sales figures for residential CFL's suggests that a technology which is perceived as inconvenient will achieve a low utilisation rate.



Policy - Replacements

Modelling of policy on replacement bulbs is dominated by the calibration factor and care needs to be taken with interpreting the results. Nevertheless, two issues are apparent from the model.

Firstly, the rate of uptake is slow relative to the potential (both of the market to supply, as well as the decision making frequency). This identifies the poor perception of EE replacements, as seen by the market. The consistency of these views over time suggests that a campaign of persuasion would have limited success and a structured phase-out of the incumbent technology is more efficient.

Secondly, the laggard population cannot be accessed, unless mandatory policies are implemented. Given that this is 30% of the population, grants and other schemes aimed at making the voluntary decision more attractive, will be relatively inefficient.

Suggestions - Standardisation of fixtures/fittings, luminaires etc. need to make EE bulbs the norm, phase out of halophosphate tubes

Fluorescents (26mm)

The importance of non-financial issues suggests that legislation/phase-out of halophosphates, would be the most effective policy. This would lead to rapid uptake as well as addressing the laggard group. The Market Transformation Programme notes that the phasing out of halophospate fluorescent tubes would offer greater impact than the phasing out of tungsten filament lamps in the non-domestic sector.

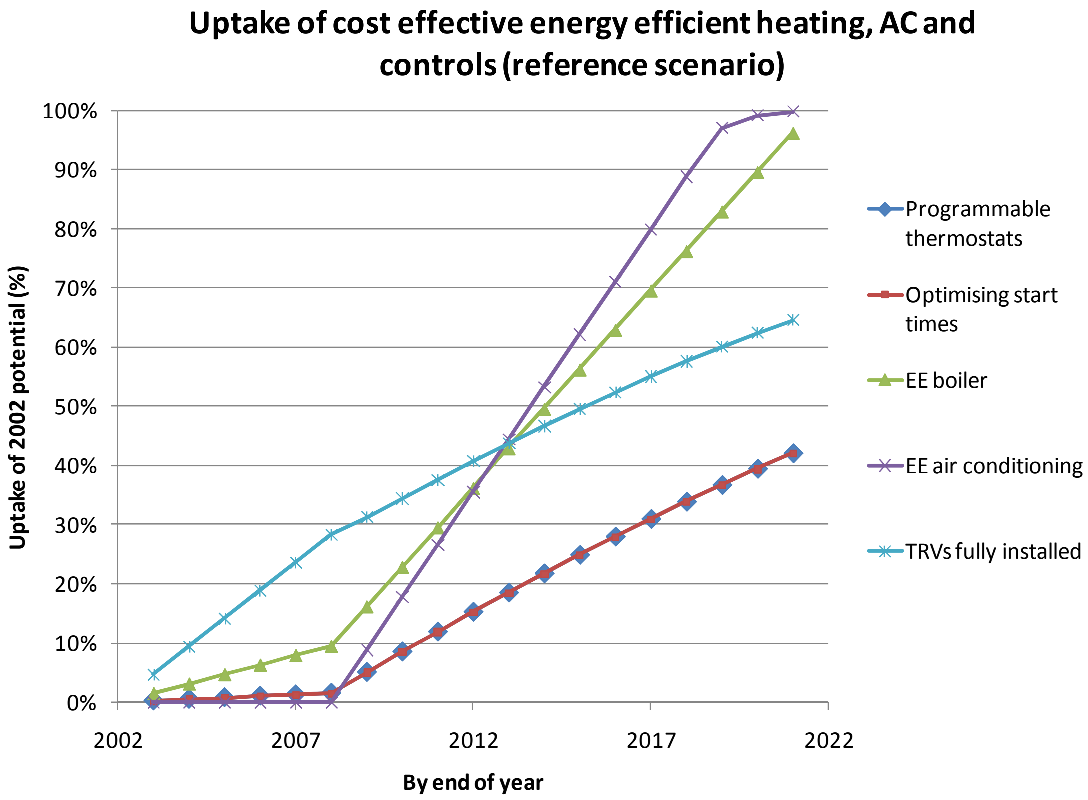
Tungsten

Purchases are likely to be influenced by UK policy decisions to phase out the most inefficient bulbs in the domestic sector, and suffer from similar barriers. In addition it is unlikely that after refurbishment, GLS lamps will be permitted under 2006 part L2B building regulations[67].

[67] Part L2B applies to buildings greater than 1000m2, for any extension, and for initial provision or increase in installed capacity of fixed building services. Measures with a simple payback <15 years are considered economic in this regulation.

6.2 Heating/Air conditioning

The majority of the 2007 (commercial sector) technical potential is represented by this sector and the rate of uptake differs significantly, split between those technologies which are essentially mandated on replacement, and discretionary controls which may be installed at the same point in time.



6.2.1 Replacement boilers

Replacement boilers are covered by guidance associated with part L, Non-Domestic Heating, Cooling and Ventilation Compliance Guide. DCLG, May 2006[68]. This specifies a minimum efficiency as described in the appendix. It is assumed, therefore that energy efficient boilers are effectively mandated and uptake therefore occurs at the replacement rate. The potential is virtually achieved by 2022 (>95%) and is limited by the boiler failure/replacement rate.

6.2.2 Air conditioning

BRE assigned no cost premium to air conditioning. Air conditioning is covered in part by regulation (though it is recognised that this legislation could be more stringent). The uptake graph here assumes mandation of energy efficient air conditioning units with savings equivalent to those modelled by BRE. The shorter lifetime of the units compared to boilers ensures all inefficient A/C units from 2002 are replaced before 2020.

This approach does not consider the expansion of the market in response to the increased demand for comfort and higher rateable values that can be achieved for air-conditioned properties.

Policy

[68] Guidance on showing compliance with paragraph 41 in Part L2B

Given the model assumption that these are replacement technologies, and that there is regulation that the replacements must be energy efficient, there is limited capability for improving uptake.

6.2.3 Optimising start times/programmable thermostats/TRVs

For controls, the Compliance Guide only specifies a basic time clock and an on/off control by zone for buildings greater than 150m2. It is therefore assumed that TRVs and programmable thermostats are discretionary, as is the optimisation of start times.

If the seasonal efficiency is less than the minimum, credits can be gained for measures such as TRVs (1% point), room thermostats (0.5% points), optimised start/stop times (2% points) and building management systems (4% points). This may act to increase the uptake of controls above the reference scenario shown in the previous graph (c.40% uptake by 2022).

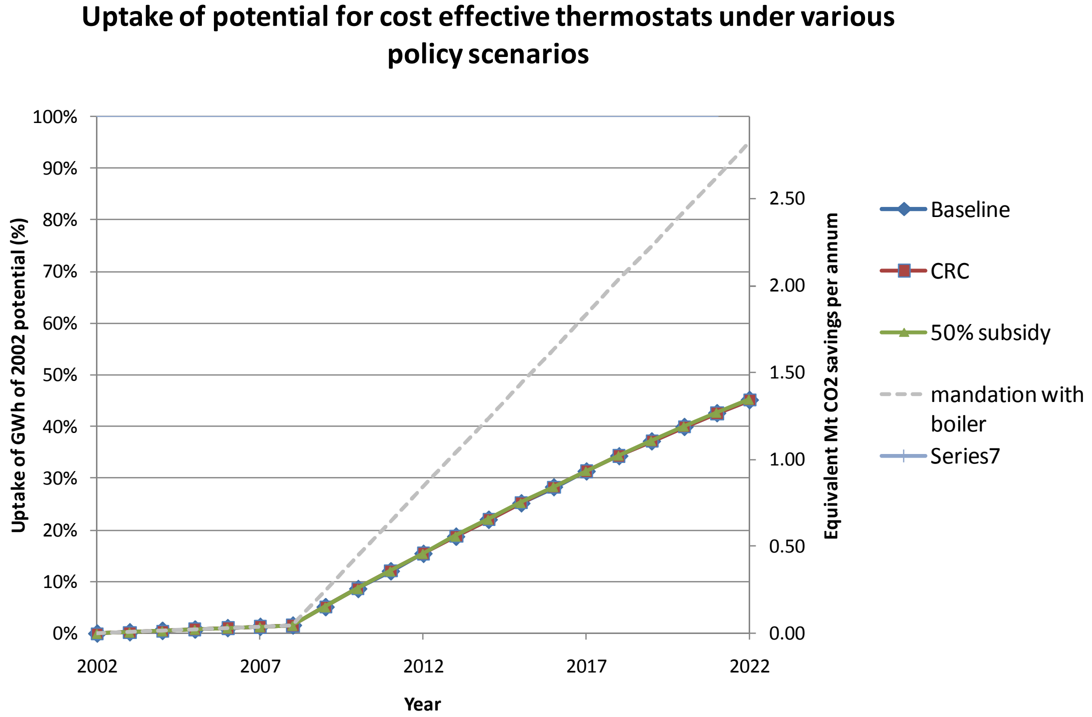
BRE predictions for the uptake for the optimisation of start times and programmable thermostats are lower (c.15% by 2022). This may be explained by the following:

- Skills/management requirements involved may signify that a c.3 year payback is not representative of the true cost/benefit
- Installers may not be recommending the controls
- Meeting minimum standard only for building regulations

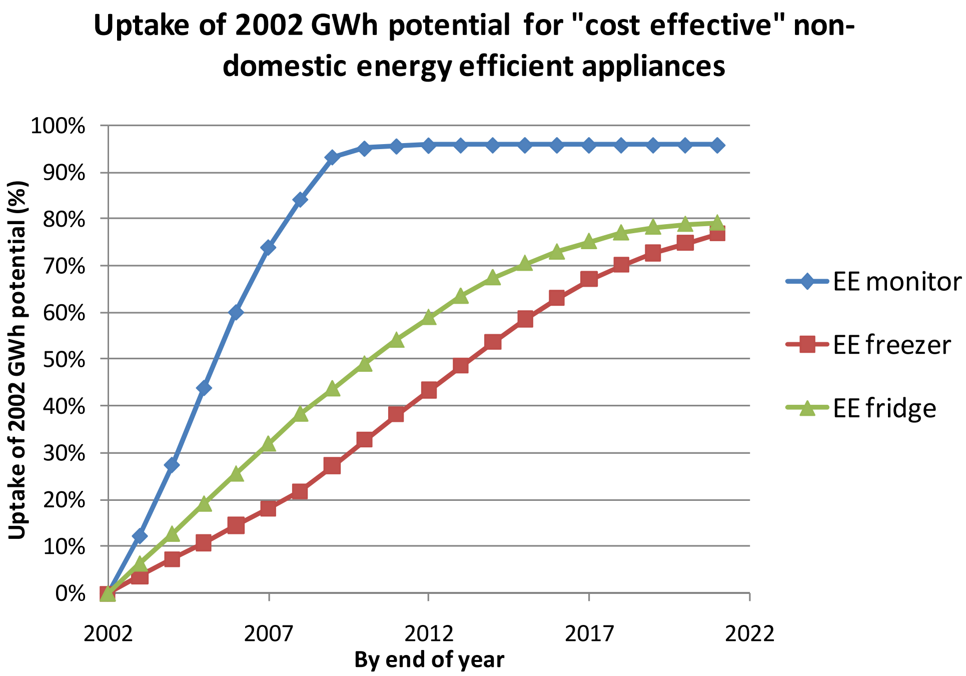
Policy

There is potential to tighten regulation to increase controls requirement in Part L. Legislation can increase uptake, however, but not proper use. Considerable skill is involved in e.g. optimising start times to achieve optimum savings, and to understand the true building energy usage. Flexibility in building use and the presence of multiple tenants in one building remain barriers to the optimisation of start times.

There is no impact on uptake of controls from the CRC as this measure is only considered when a boiler is replaced at present. The capital cost of the control is not the primary impediment, hence no impact of 50% subsidy. Mandation at the point of replacement of the boiler, however, results in near realisation of the technical potential by 2022. These savings require good management of the controls to be achieved and therefore support in their use is essential.



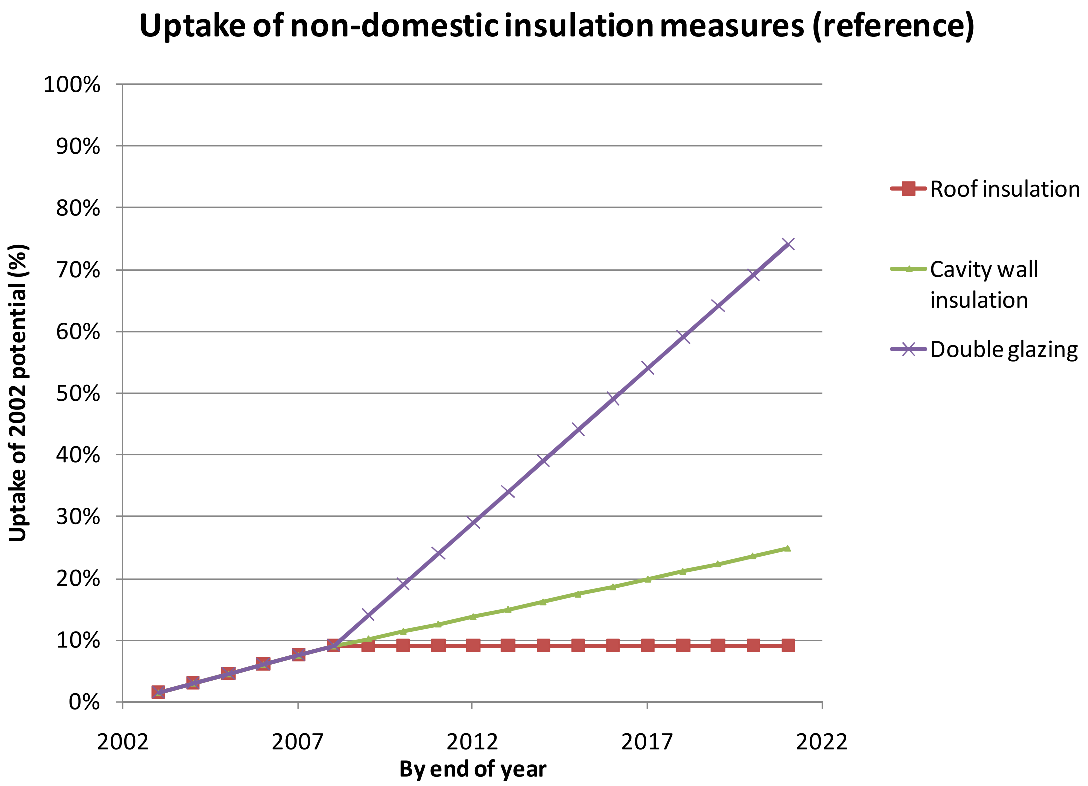
6.3 Appliances



Reference Scenario & Policy.
In the reference scenario the uptake of EE monitors shows historically high penetration rates. This high uptake is believed due mainly to aesthetic/performance/space saving reasons and not energy efficiency. Saturation is predicted by 2011 without any additional policy intervention.

The model shows good fit with historical BRE estimates for fridges and freezers. Due to the problems of modelling decision making these sectors with a financial approach (as discussed previously) and the limited CO_2 saving potential, no further modelling of this sector was attempted.

6.4 Insulation



Reference Scenario
The BRE model had a single level of uptake for insulation measures shown, this is shown in the graph as the line up to 2008. If extrapolated linearly out to 2022, this would suggest an uptake of approximately 36%. Comparing this with the graph above, we can see a prediction of a higher uptake of double glazing, a slightly lower uptake of cavity wall, and almost zero roof insulation.

Double glazing is assumed to be mandated at the point of replacement, and this defines the uptake rate. Cavity wall insulation achieves a low but steady rate of uptake as properties are refurbished. Flat and pitched roof insulation is predicted to achieve near zero uptake, due to the long payback periods and the capital cost sensitivity of the consumer.

6.5 Energy management

It was not possible to model energy management measures in the same way as the rest of the measures as the energy savings could not be tied to the associated number of hours required to invest in their implementation.

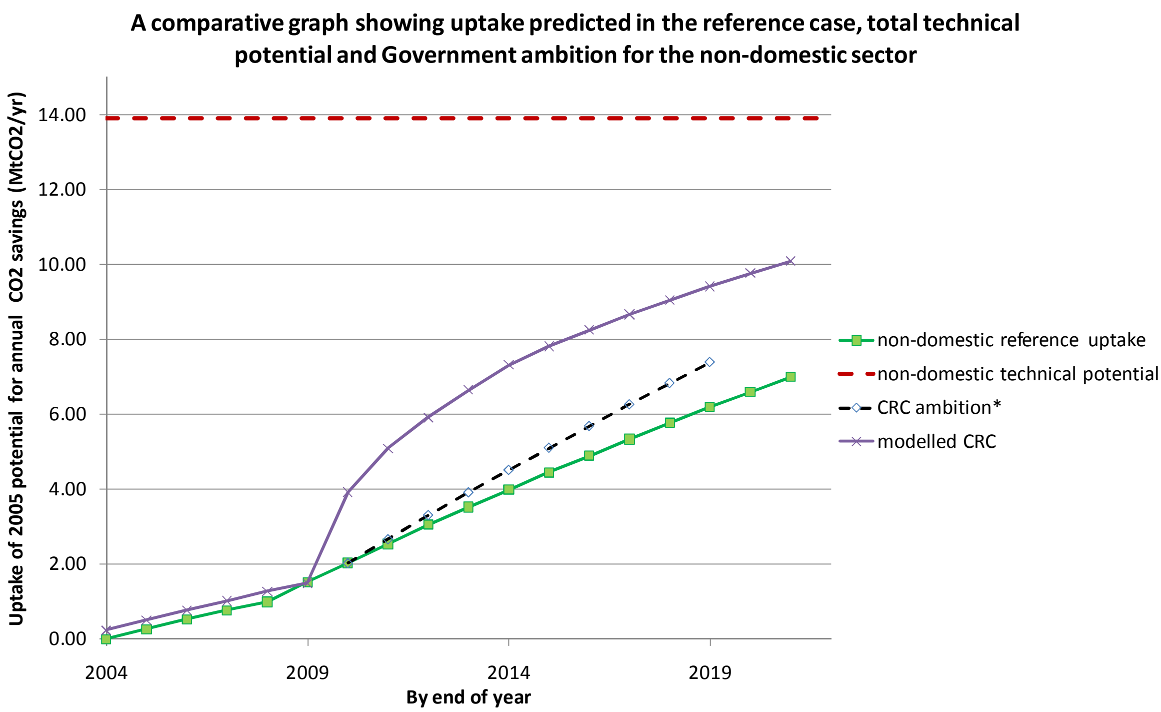
7 CONCLUSIONS AND AMBITION– NON-DOMESTIC SECTOR

Reference scenario

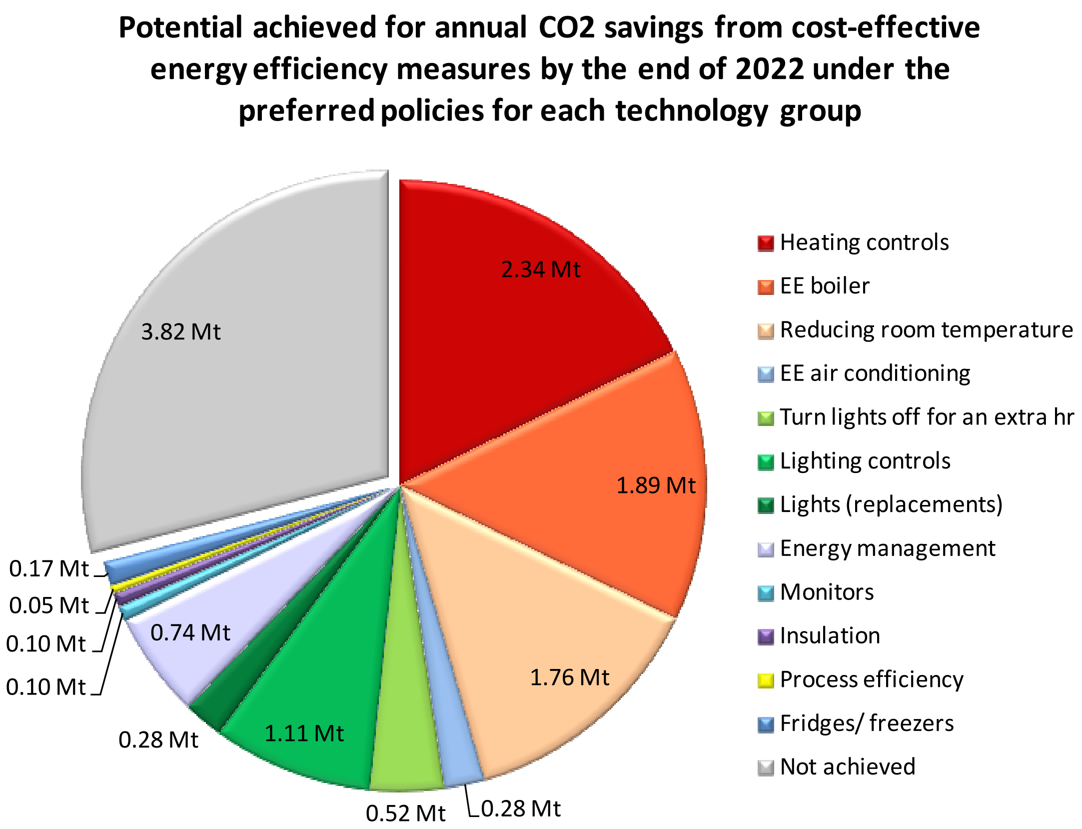
Our calculations for the reference scenario assume that the replacement of boilers and air conditioning units by their energy efficient counterparts is covered by guidance associated with part L (Non-Domestic Heating, Cooling and Ventilation Compliance Guide). We therefore have taken an optimistic view of what regulation in this area can achieve, and our figure should be read as an upper bound for uptake (for more details see appendix).

Levels of ambition

The graph below shows the modelled non-domestic reference case, and a modelled CRC policy, with the current ambition for this policy shown for reference. The approach taken here results in an optimistic and early increase in uptake for energy efficiency measures as a result of a boost in decision-making frequency directly related to increased awareness caused by the CRC and associated programmes. This increase therefore begins prior to the official start date of the programme.



The most ambitious level of savings achieved during our analysis is shown in the pie chart below and over 9.3 Mt of CO_2 savings are achieved per annum, leaving c. 3.8 Mt of potential unrealised.

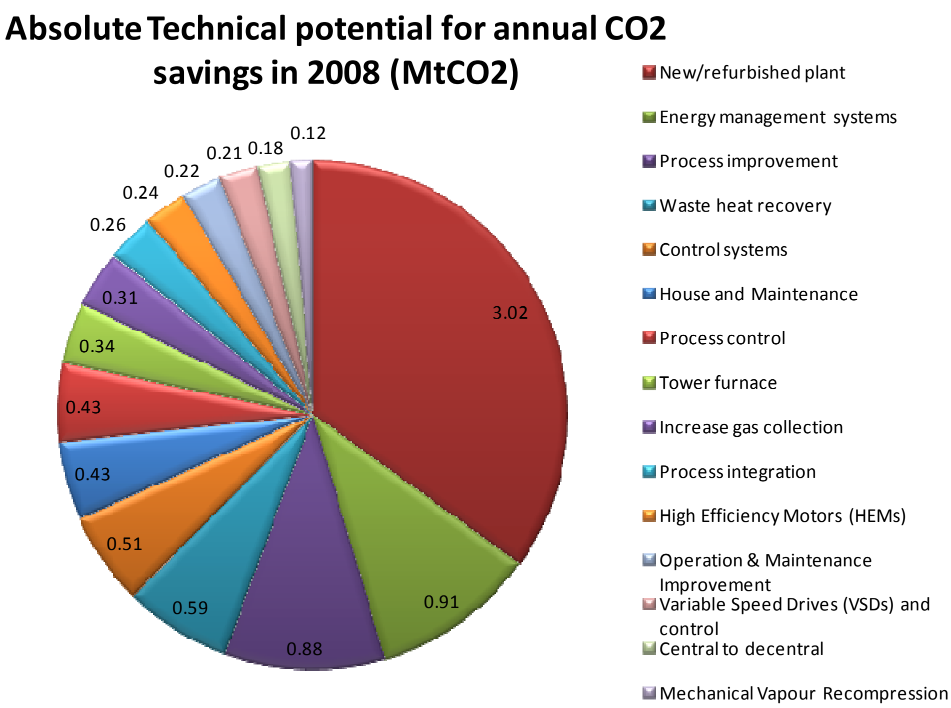

Potential achieved for annual CO2 savings from cost-effective energy efficiency measures by the end of 2022 under the preferred policies for each technology group
2.34 Mt
1.89 Mt
1.76 Mt
0.28 Mt
0.52 Mt
1.11 Mt
0.28 Mt
0.74 Mt
0.10 Mt
0.10 Mt
0.05 Mt
0.17 Mt
3.82 Mt
Heating controls
EE boiler
Reducing room temperature
EE air conditioning
Turn lights off for an extra hr
Lighting controls
Lights (replacements)
Energy management
Monitors
Insulation
Process efficiency
Fridges/ freezers
Not achieved

Part 3: Industrial Sector

This study considers 15 technology groups, derived from a review of the ENUSIM data and analyses the likely uptake of these measures over the period 2008-2022. Enviros reviewed the payback periods, technology lifetimes and key barriers for each technology and assessed the impact of removing these barriers as percentage increase in uptake. More details of this review can be found in the appendix.

8 STATE OF THE STOCK/EXISTING DATA

The pie chart below describes the technical potential identified through ENUSIM for annual CO2 savings for the 15 measures. The technical potential is dominated by three technology groups: new and refurbished plants, energy management systems and process improvements. The remaining measures are of roughly equal importance.



Technology/ Measure	Description	TP in 2008 (MtCO2)
House and Maintenance	Direct energy saving resulting from computerized system which monitors energy consumption.	0.43
Energy management systems	Indirect energy saving resulting from an improved understanding of the manufacturing process and removal un-necessary components and prevention of heat rejects.	0.91
Control systems	Indirect energy saving resulting from computer-based systems that monitor and control manufacturing processes in order to improve its quality.	0.51
Process control	Indirect energy saving resulting from computerised system for quality control.	0.43
Process improvement	Direct and indirect energy saving resulting from improved housekeeping and ensuring a high level of maintenance for optimum performance and longevity.	0.88
Waste heat recovery	Direct energy saving resulting from the recovery of waste heat from manufacturing processes and other sources as energy generation.	0.59

Technology/ Measure	Description	TP in 2008 (MtCO2)
Tower furnace	Direct energy saving resulting from more efficient electric arc furnaces for high temperature processing in the steel industry.	0.34
Increase gas collection	Indirect energy saving resulting from the recovery of useful by-products (gases) that can be used as an energy source.	0.31
Process integration	Indirect energy saving resulting from the integration of the different stages/ components of the manufacturing process, so that energy can be transferred between stages.	0.26
High Efficiency Motors (HEMs)	Direct energy efficiency resulting from the deployment of motors with higher efficiency.	0.24
Operation & Maintenance Improvement	Indirect energy efficiency resulting from an increased level of maintenance (i.e. above the minimum required for operation) in order to achieve better/optimum performance.	0.22
Variable Speed Drives (VSDs) and control	Direct energy saving resulting from the optimisation of the speed of motors to what is actually required at given time/stage of the manufacturing process.	0.21
Mechanical Vapour Recompression	Direct energy saving resulting from the use of a blower or compressor to increase the pressure of the vapour and consequently increase the condensation temperature.	0.12
Central to decentral	Indirect energy saving resulting from localising (or 'decentralising') heat systems such as boilers instead of singe large central systems with long distribution network.	0.18
New/refurbished plant	Energy saving resulting from refurbishment of existing plant or completely new plant which is more efficient in terms of its energy consumption per unit of product.	3.02

The ENUSIM data on 2008 market penetration and growth rates made available by CCC for this project was reviewed by Enviros and found to be incomplete (i.e. not available for some measures), outdated (i.e. many of the underlying assumptions are over 5 years old) and heavily dependent on fuel price assumptions.

The ENUSIM market data was therefore complemented with information from published studies, internal discussions with Enviros technical experts and consultation with industry stakeholders. The majority of the figures are consistent with the ENUSIM data, however, for some of the measures there are considerable differences. For more information on this work, see appendix.

9 INDUSTRIAL DECISION-MAKERS

The percentage of businesses coming forward to make a decision each year was defined for each technology group using data from the Industrial Assessment Centers Database from the United States. This is a database which collates together all publicly available assessment and recommendation data for energy efficiency measures in the USA.

The percentage of total businesses that considered each measure in 2008 varied by technology from close to zero for localising or decentralising heat systems to c.6-7% for control systems. The exact percentages used to calculate results can be found in the appendix.

In this study we do not assume in the reference scenario that the number of decision-makers each year increases over time.

10 WILLINGNESS TO PAY

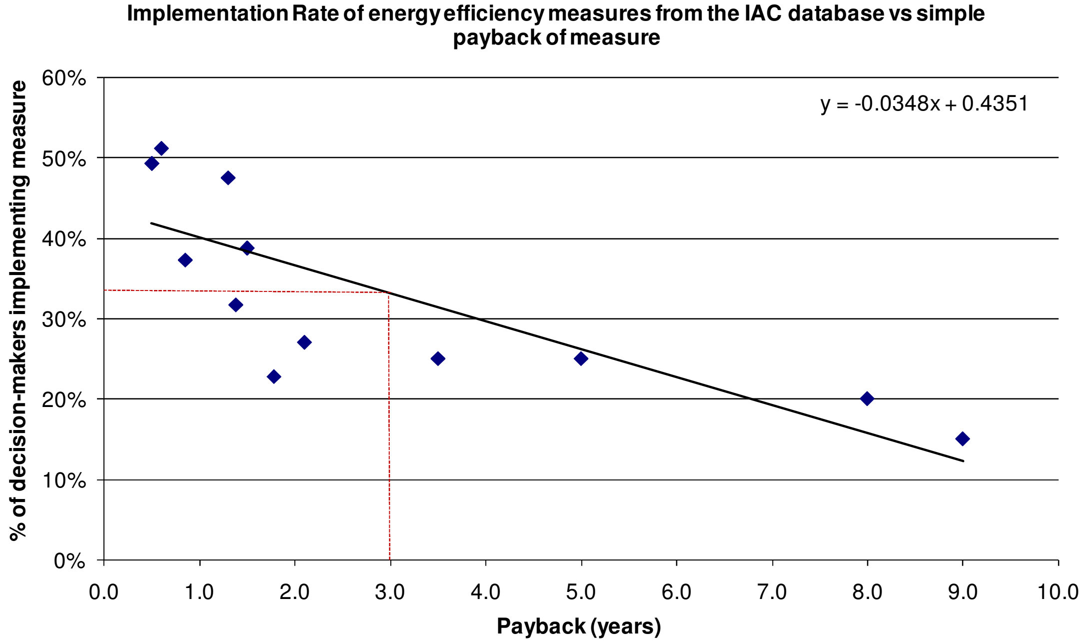
The IAC database was also used to define the implementation rate for those who considered the measure. As for the domestic and non-domestic sectors, this implementation rate was assumed to vary dependent on the simple payback period of the technology. This is supported by the IAC 2008 data, and past work by Enviros[69].

The following graph shows the real data points for the technologies considered and the trend line used in the following analysis[70]. From this relationship, an energy efficiency measure with a payback of 3 years will have an implementation rate of c.33%. In this case 6% of the

[69] Enviros Consulting Ltd (2006) Review and development of carbon dioxide abatement curves for available technologies. Energy Efficiency Innovation Review for Defra.

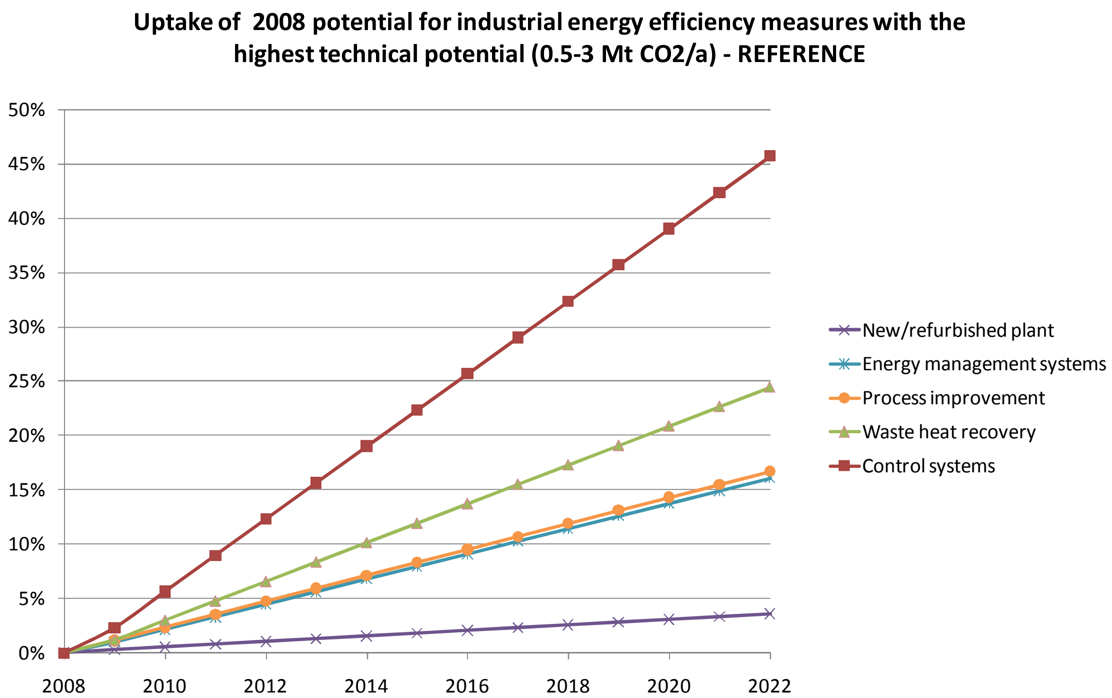
[70] One outlier was removed from the datase

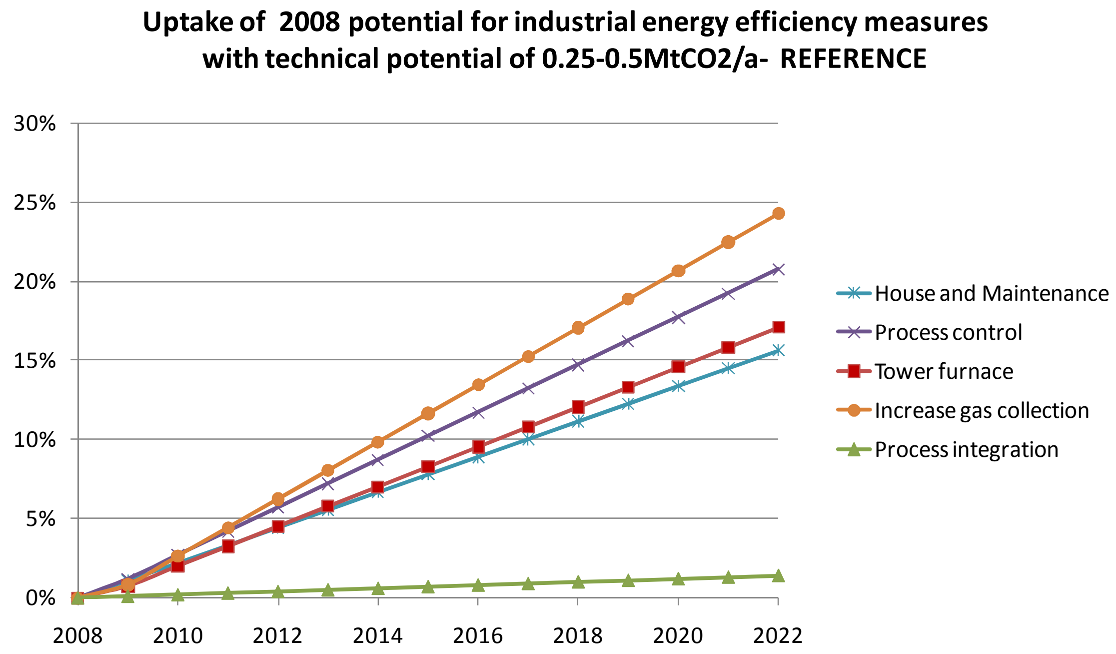
population come forward to make the decision regarding this measure each year it would therefore take c.50 years to saturate the market at this rate.

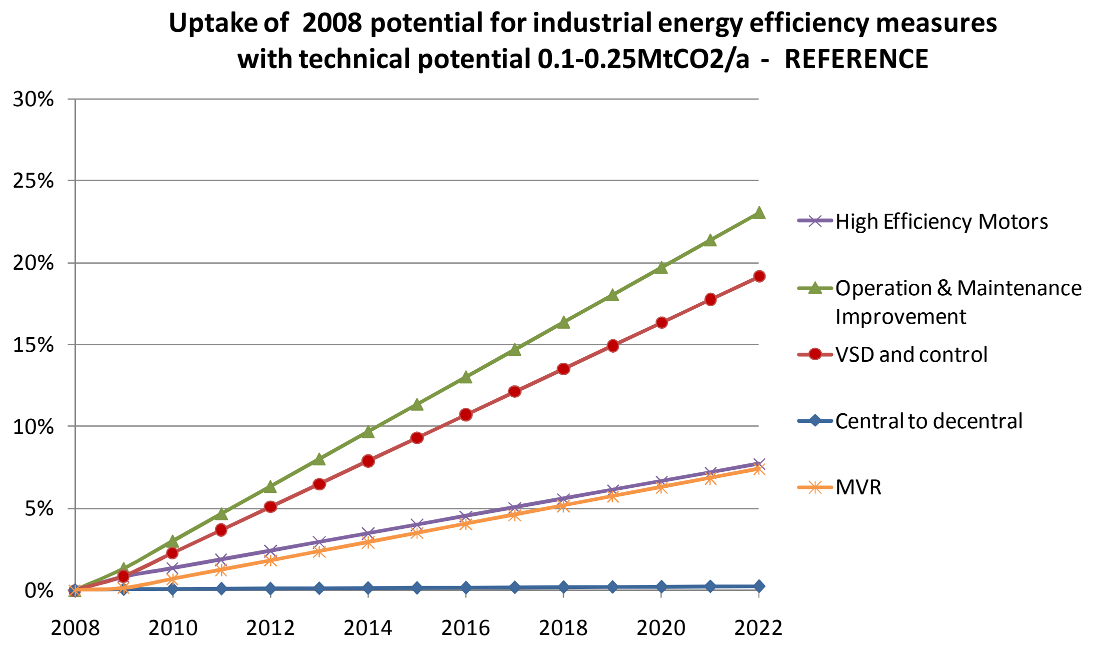


11 RESULTS - REFERENCE SCENARIO

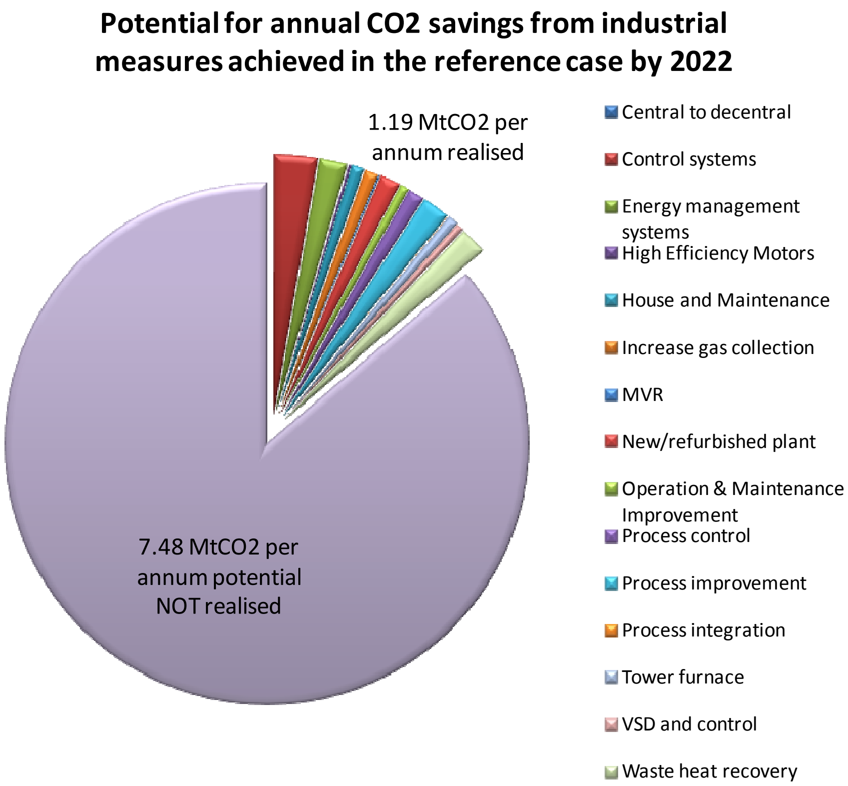
The following graphs show the predicted uptake in the reference case based on the number of decision-makers and willingness to pay equation described above. Unlike the domestic and non-domestic sectors, the composition of the population is not assumed to change through time (i.e. there is no process for accounting for laggards) and therefore linear uptake is always predicted.
The results are presented in order of their overall technical potential in 2008, as defined by ENUSIM (see appendix).







In all cases the uptake of the 2008 potential for measures is severely restricted by the number of businesses coming forward each year (as defined by Enviros from the IAC database). The highest rate of uptake is observed for control systems, which in turn are associated with the highest consideration rate of all technologies. Measures with estimated payback periods over 5 years also suffer from low implementation rate unless regulation is imposed upon them; such schemes include replacement or refurbishment of plants and moving from central to decentralised energy.



12 POTENTIAL POLICY/ACTIONS

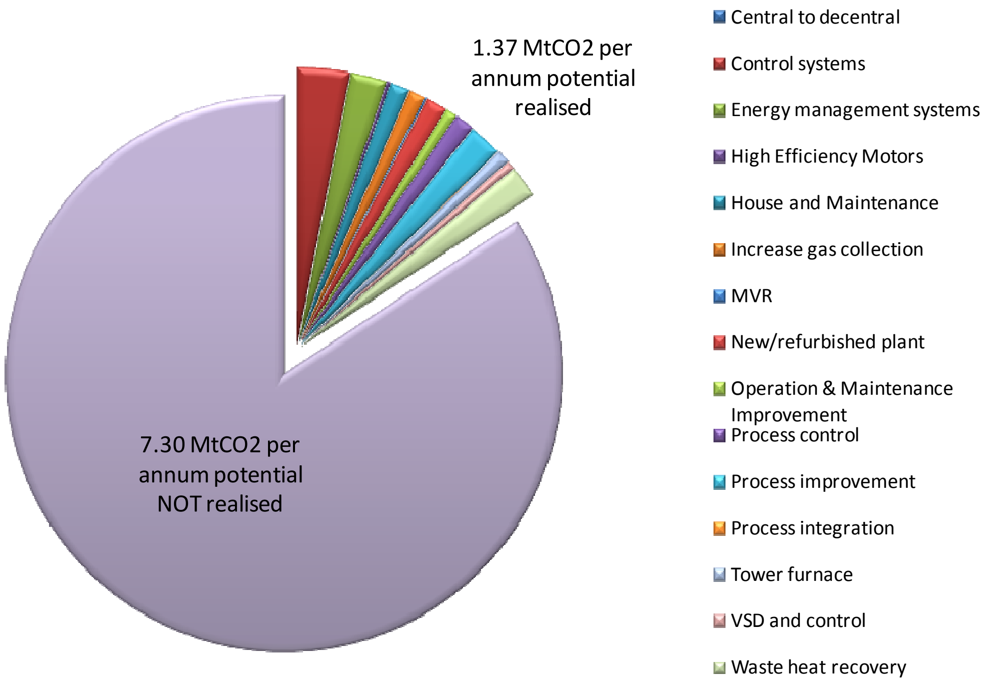
As part of this study Enviros identified 9 potential barriers to the uptake of industrial measures, and for each technology determined the three most important factors; details of how these were derived can be found in their associated report.
The barriers are listed below with actions proposed by Enviros to overcome part of the issue. For each technology they assessed the potential increase in uptake as a result of the actions listed. The resultant uplift ranged from 1-20%.
This increase was applied to the cumulative sales per year defined in the reference scenario, for example, if half a million sales were predicted in the baseline in 2009 and an applied action raised uptake by 2% then 510,000 measures would be installed in 2009. If the action was still relevant in the following year, the same methodology was applied.

The following table lists the actions identified by Enviros.

Barrier	Action
Lack of technical awareness	Publish advice and fund case studies
Management resource	Employ consultant, support suppliers to provide standard low cost solutions, carry out an awareness campaign
Lack of financial awareness	Publish benchmarking guidelines, case studies and create network events/publicity
Unrealistic payback expectations	Benchmarking, case studies, scoping studies, demonstration projects
Competitive capital demand	Change/expand Energy Technology List
Poor quality savings predictions	Benchmark ways to improve predictions and dissemination of information
Available credit and cost of credit	Subsidy for verified savings tax relief
Impact of limited production life	Tax relief and grants
Over estimation of risks	Partially fund feasibility studies

These actions are more commonly related to increasing uptake among decision-makers rather than increasing the decision-making frequency of the population and as such have a restricted impact on achieving the overall potential.
The following pie chart demonstrates the savings achieved if for each technology, the three most effective actions are taken. These actions result in an additional saving of c.0.18 $MtCO_2$ per annum by 2022.

Potential for annual CO2 savings from industrial measures achieved after actions by 2022



	2008 Technical potential	Annual savings potential realised by 2022 (after actions)
Central to decentral	0.18	0.00
Control systems	0.51	0.26
Energy management systems	0.91	0.18
High Efficiency Motors	0.24	0.02
House and Maintenance	0.43	0.10
Increase gas collection	0.31	0.08
MVR	0.12	0.01
New/refurbished plant	3.02	0.11
Operation & Maintenance Improvement	0.22	0.06
Process control	0.43	0.10
Process improvement	0.88	0.17
Process integration	0.26	0.00
Tower furnace	0.34	0.07
VSD and control	0.21	0.04
Waste heat recovery	0.59	0.16

APPENDIX

13 ACKNOWLEDGEMENTS

Element Energy wishes to thank the following organisations for providing data and insight used for parts of this study. Any inaccuracies remain the responsibility of Element Energy Ltd.

- The Carbon Trust
- Confederation of British Industry
- British Electrotechnical and Allied Manufacturers' Association
- The Association of Controls Manufacturers
- The Department of Energy and Climate Change
- Energy Efficiency Partnership for Homes
- Energy Savings Trust
- Ecofys
- Members of the Insulated Render and Cladding Association (INCA)

Particular thanks go to Stuart Farmer, Colin Timmins, Nicholas Taylor, Ben Castle, Mark Brown, Rachel Castle, James Greenleaf and Brian Samuel.

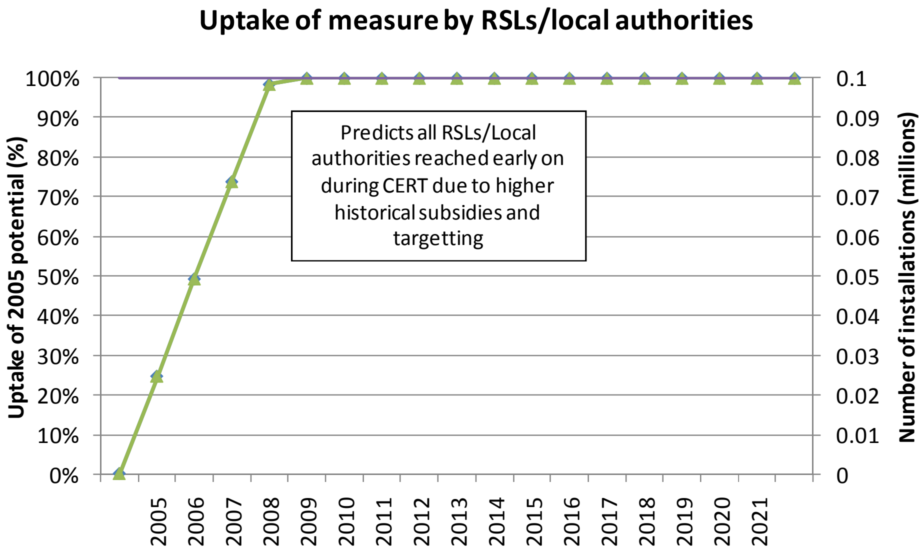
14 GLOSSARY

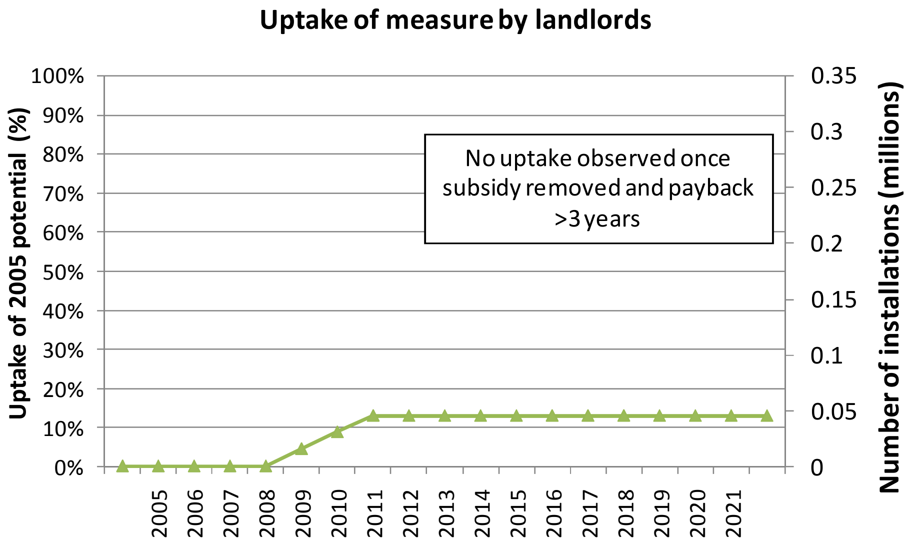
BERR – Department for Business, Enterprise and Regulatory Reform
CERT – Carbon Emissions Reduction Target (an energy supplier obligation)
CaRB project – Carbon Reduction in Buildings Project
CRC – Carbon Reduction Commitment
CWI – Cavity wall insulation
DEC – Display energy certificate
DEFRA – Department for the Environment, Food and Rural Affairs.
DCLG – Department for Communities and Local Government
EE – Energy efficient
EEC – Energy Efficiency Commitment
EEPH – Energy Efficiency Partnership for Homes
EHCS – English House Condition Survey
EPC – Energy Performance Certificate
EST- Energy Saving Trust
GLS lamp – General lighting service lamp
GW – Gigawatt (1 GW = 10^9 W)
GWh – Gigawatt hour (1 GWh = 10^6 kWh)
HF ballast – High frequency ballast
HVAC – Heating, ventilation and air conditioning
IAC – Industrial assessment center
IRC – Infra-red coated
kW – a unit of power
Microgeneration – Small scale systems that can provide heat or power with lower CO_2 emissions than conventional alternatives. The government's definition of microgeneration is <50 kW_e and <45 kW_{th}.
Mt CO_2 – Million tonnes of carbon dioxide.
MTP – Market Transformation Programme
MW – Megawatts (a unit of power)
MWh – Megawatt hour (a unit of energy)
N-DEEM - National Non-Domestic Energy and Emissions Model
SME – Small and medium enterprises
SWI – Solid wall insulation
TRV – Thermostatic radiator valve
RSL – Registered social landlord
WTP – Willingness to pay

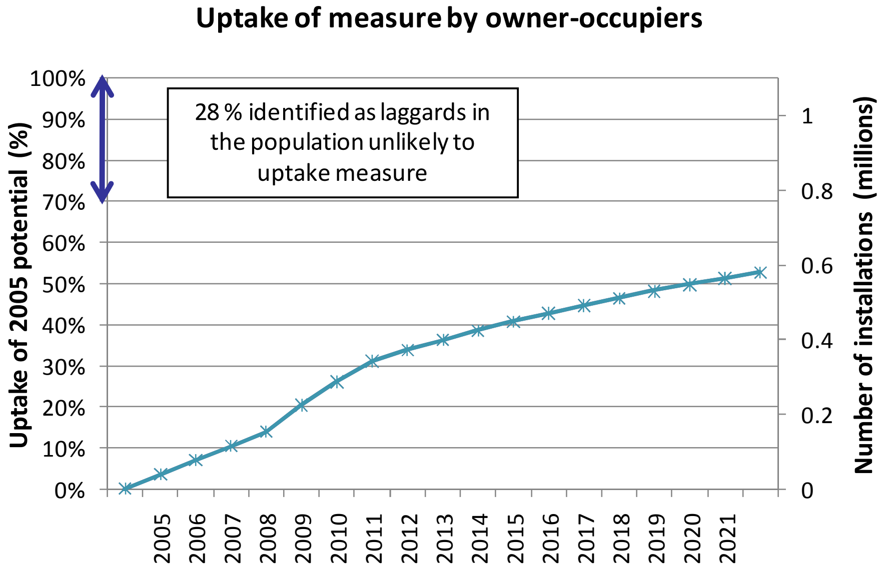
15 TECHNICAL NOTES

15.1 Uptake by different user types

The residential uptake curves are an aggregation of the uptake results for the different user types, social landlords, private landlords and owner occupiers; each group can be shown to have distinctly different uptake profiles and have varying starting potentials dependent on historic uptake rates.
The following graphs show the differences in uptake of cavity wall insulation in the reference scenario.

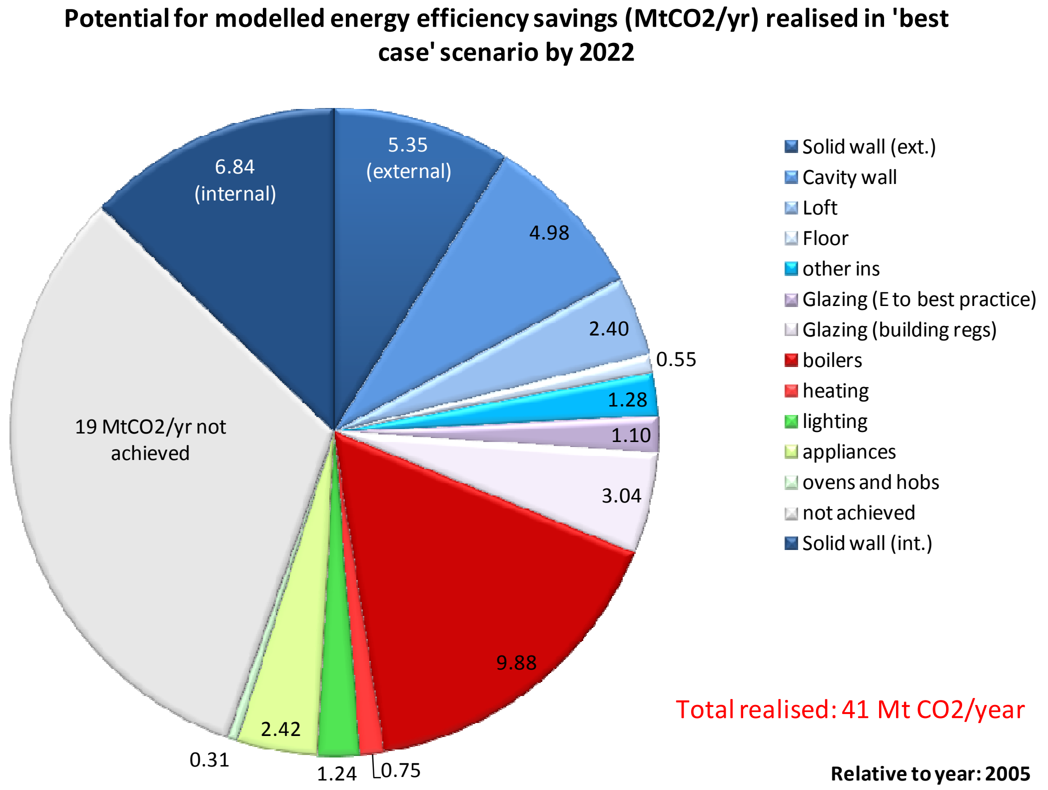


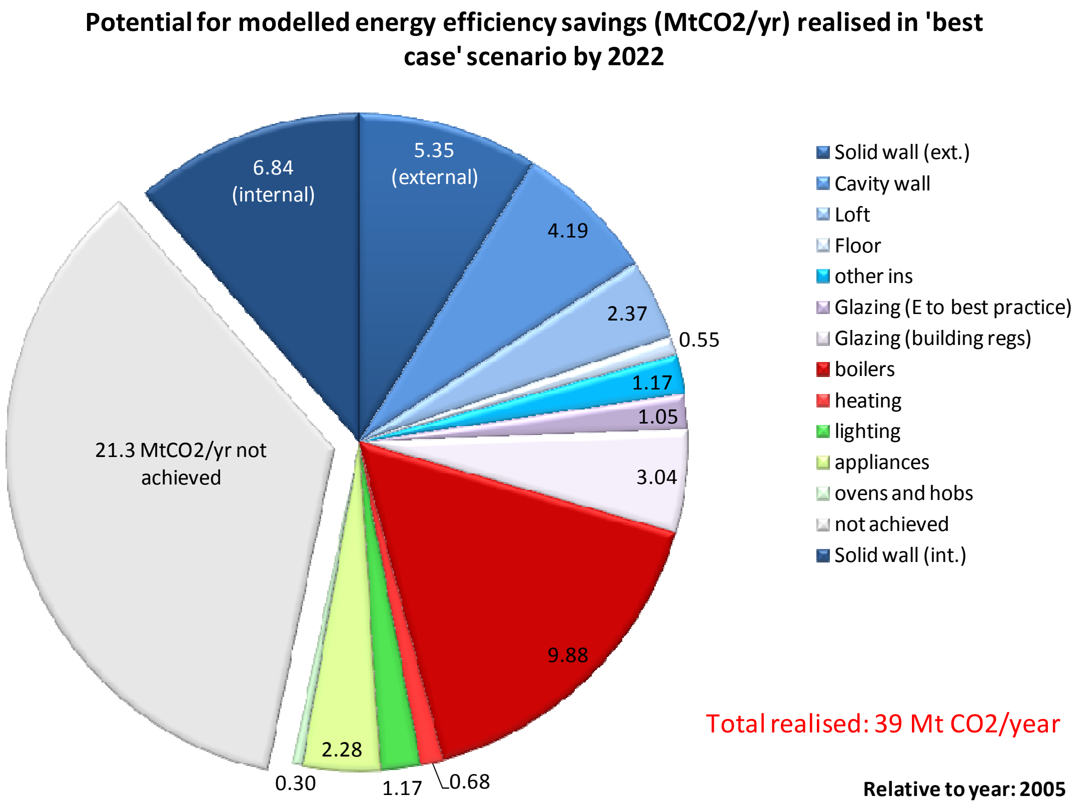




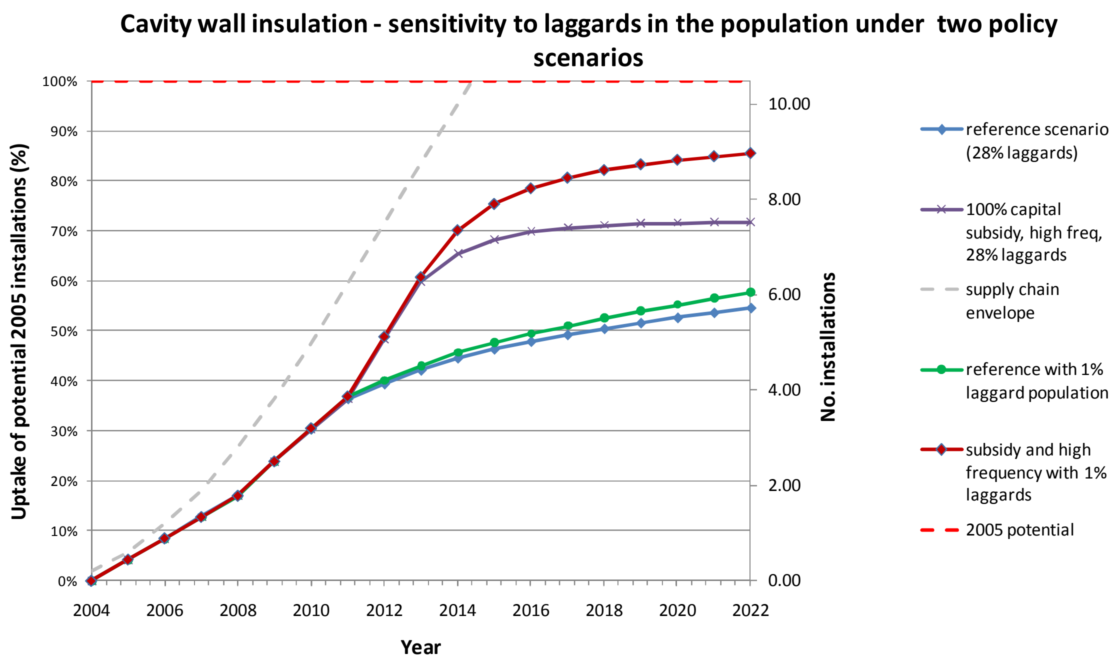
15.2 Laggard sensitivity analysis

The percentage of laggards identified in the population primarily impacts on technologies which are not constrained by the decision-making frequency restrictions of replacement technologies and which are not already severely constrained by the supply chain/ industry expansion. The following pie charts demonstrate that an additional 2Mt of CO_2 saving is achieved by vastly reducing the laggard population from the reference case, 28% (upper chart) to 1% of the population (lower chart).



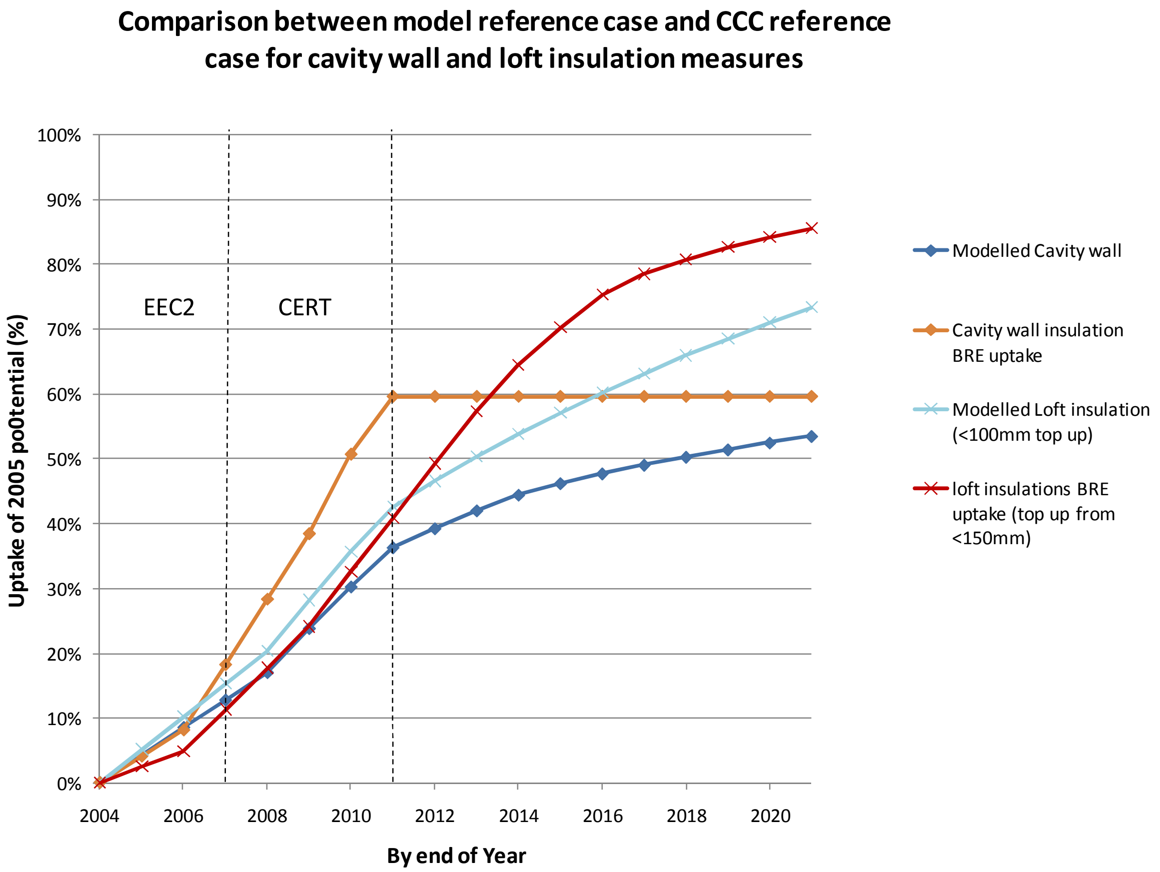


Half of this additional saving is the result of increased uptake for cavity wall insulation, where uptake can be increased by over 10% by 2022 if the laggard proportion of the population is essentially removed.



15.3 Comparison between domestic model reference scenario and CCC reference case

The following graph is included as an example of the differences in trajectories predicted by BRE and by the modelling undertaken in this work.



15.4 Comparison between non-domestic model reference scenario and CCC reference case

Our calculations assume that the replacement of boilers by their energy efficient counterparts is covered by guidance associated with part L (Non-Domestic Heating, Cooling and Ventilation Compliance Guide). We therefore have taken an optimistic view of what regulation in this area can achieve, and our figure should be read as an upper bound for the baseline. In contrast the original BRE data suggests c.69% of potential is still remaining in 2022.

BRE predictions for the uptake for the optimisation of start times and programmable thermostats are lower than the figures calculated from our modelling (c.15% by 2022 compared to c.30-40%). This may be explained by the following:

- Skills/management requirements involved may signify that a c.3 year payback is not representative of the true cost/benefit
- Installers may not be recommending the controls
- Meeting minimum standard only for building regulations

More minor differences include:

- Appliances – more optimistic view of uptake (given the current prevalence of LCDs, market transformation programme data and rate of change of office ICT equipment)
- Air conditioning – more optimistic view of replacement of 2002 systems with energy efficient equivalents based on some degree of mandation via the Non-Domestic Heating, Cooling and Ventilation Compliance Guide

15.5 Domestic supplementary data

Measure	Total potential MtCO2 saving (2005)	Lifetime	Apparent capital cost from BRE/AEA	Apparent capital cost - Element review and consultation	Additional engineering	Upfront time cost (hidden + information)	Change in Annual fuel cost (total)	Total installed cost
Pre76 cavity wall insulation	5.19	40	£350.00	£380.10	£0.00	£21.96	£107.33	£402.06
76-83 cavity wall insulation	0.37	40	£350.00	£380.10	£0.00	£21.96	£57.10	£402.06
Post '83 cavity wall insulation	0.20	40	£350.00	£380.10	£0.00	£21.96	£31.66	£402.06
Solid wall insulation external	14.08	40	£4,000.00	£6,800.00	£1,500.00	£56.12	£314.04	£8,356.12
solid wall insulation internal	14.08	40	£4,000.00	£5,600.00	£59.12	£102.48	£314.04	£5,761.60
Loft insulation 0 - 270mm	1.02	40	£250.00	£286.20	£0.00	£65.88	£111.76	£352.08
Loft insulation 100 - 270mm	0.07	40	£200.00	£286.20	£0.00	£65.88	£48.88	£352.08
Loft insulation 125 - 270mm	0.25	40	£180.00	£286.20	£0.00	£65.88	£29.54	£352.08
Loft insulation 150 - 270mm	0.45	40	£150.00	£286.20	£0.00	£65.88	£20.35	£352.08
Loft insulation 25 - 270mm	0.51	40	£240.00	£286.20	£0.00	£65.88	£14.87	£352.08
Loft insulation 50 - 270mm	0.17	40	£230.00	£286.20	£0.00	£65.88	£11.48	£352.08
Loft insulation 75 - 270mm	0.18	40	£220.00	£286.20	£0.00	£65.88	£7.46	£352.08
DIY floor insulation (susp. timber floors)	1.38	40	£150.00	£800.00	£0.00	£117.12	£39.45	£917.12
Installed floor insulation (susp.TFs)	1.38	40	£500.00	£800.00	£0.00	£75.64	£39.45	£875.64
Glazing - single to building regs 2006	3.63	25	£0.00	£0.00	£0.00	£0.00	£79.26	£0.00
Glazing - old double to to building regs 2006	2.70	25	£0.00	£0.00	£0.00	£0.00	£29.51	£0.00
Building regs double to "future double"	3.64	25	£500.00	£500.00	£0.00	£0.00	£26.44	£500.00
Insulated doors	1.69	25	£0.00	£0.00	£0.00	£0.00	£11.65	£0.00
Improve airtightness	0.80	25	£200.00	£101.00	£0.00	£31.72	£17.46	£132.72
A-rated condensing boiler	9.88	15	£0.00	£0.00	£0.00	£0.00	£97.70	£0.00
Room thermostat to control heating	0.29	15	£250.00	£250.00	£0.00	£21.96	£22.69	£271.96
Thermostatic radiator valves	0.54	15	£100.00	£148.40	£0.00	£21.96	£7.87	£170.36
Hot water cylinder 'stat	0.09	15	£250.00	£148.40	£0.00	£21.96	£3.06	£170.36
Uninsulated cylinder to high performance	0.86	20	£400.00	£400.00	£0.00	£21.96	£113.46	£421.96
Modestly insulated cyl to high performance	0.48	20	£400.00	£400.00	£0.00	£21.96	£20.29	£421.96
Insulate primary pipework	0.62	15	£30.00	£30.00	£0.00	£31.72	£9.53	£61.72
A++ rated cold appliances	4.35	15	£20.00	£21.20	£0.00	£4.88	£42.08	£26.08
A+ rated wet appliances	2.31	8	£10.00	£90.00	£0.00	£4.88	£22.42	£94.88
Efficient lighting	3.30	10	£100.00	£100.00	£0.00	£2.44	£35.29	£102.44
Integrated digital TVs	0.82	7	£0.00	£0.00	£0.00	£2.44	£7.94	£2.44
Reduced standby consumption	1.37	7	£0.00	£0.00	£0.00	£2.44	£13.24	£2.44
A rated ovens	0.72	15	£10.00	£10.00	£0.00	£4.88	£13.68	£14.88
Induction hobs	0.67	15	£50.00	£50.00	£0.00	£4.88	£13.68	£54.88
DIY loft insulation	1.95	40	£120.00	£120.00	£0.00	£73.20	55.44	£193.20

	Post '83 cavity wall insulation	Solid wall insulation (external)	solid wall insulation (internal)	Loft insulation 0 - 270mm	Loft insulation 25 - 270mm	Loft insulation 50 - 270mm to 150-270mm	DIY floor insulation	Installed floor insulation	Glazing - single to part L	Glazing - old double to part L	Upgrade part L to "future" double	Insulated doors	Improve airtightness
EEC 2 subsidy	60%	15%	15%	64.80%	64.80%	49.50%	0%	0%	0%	0%	4%	4%	44%
CERT subsidy (non-priority group)	56%	47%	46%	64%	64%	64%	0%	0%	0%	0%	50%	0%	76%
CERT subsidy (priority group)	90%	85%	81%	89%	89%	89%	0%	0%	0%	0%	0%	0%	93%

	A-rated condensing boiler	Room thermostat or TRVs	Hot water cylinder 'stat	Uninsulated cylinder to high performance	Modestly insulated cyl. to high performance	Insulate primary pipework	A++ rated cold appliances	A+ rated wet appliances	Efficient lighting	Integrated digital TVs	A rated ovens /hobs
EEC 2 subsidy	49%	49%	49%	9.60%	9.60%	9.60%	37%	33%	63.20%	0%	0%
CERT subsidy (non-priority group)	0%	43%	43%	80.40%	80.40%	80.40%	52%	51%	45.55%	50%	0%
CERT subsidy (priority group)	0%	75%	75%	95.10%	95.10%	95.10%	57%	50%	78.24%	50%	0%

15.6 Non-domestic supplementary data

Non-domestic boilers

Required minimum effective heat generating seasonal efficiencies and minimum boiler seasonal efficiency for boiler systems in existing buildings		
	Minimum Effective Heat Generating Seasonal Efficiency (% gross calorific value)	Minimum boiler seasonal efficiency (% gross calorific value)
Gas (natural)	84	80
Gas (LPG)	85	81
Oil	86	82

Minimum controls package for replacement boilers in existing buildings	
Minimum controls package for replacement boilers	Suitable controls
Zone controls	Zone control is required only for buildings where floor area>150m^2. As a minimum on/off control should be provided.
Demand controls	Room thermostat which controls through a diverter valve with constant boiler flow water temperature. This method of control is not suitable for condensing boilers.
Time controls	Time clock controls

Market penetration for lights

	Market Penetration estimate				
	Triphosphor (T8)	Metal halide	CFLs (for GLS)	Low-loss ballast	Infra red halogen
2002	0%	0.00%	0%	0%	0%
2003	5.1%	0.06%	3.7%	4.5%	0%
2004	10.1%	0.11%	7.9%	8.9%	0%
2005	13.5%	0.18%	11.9%	12.0%	0%
2006	15.7%	0.20%	16.5%	14.1%	0%
2007	18.2%	0.23%	21.2%	16.3%	0%
2008	20.4%	0.26%	25.8%	19.6%	0%
2007 BRE estimate	32%	6%	6%	17%	6%