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Executive Summary

- In 1998 BRE published the "Non-Domestic Energy Fact File" which provided information on the existing stock of non-domestic buildings and reported preliminary estimates of carbon emissions and energy consumption by building type. Since that report was published the state of knowledge in this field has advanced significantly. As a result this report can provide a far more comprehensive understanding of energy use and emissions from non-domestic buildings and the potential for reducing emissions. A companion report for the housing sector has also been produced.
- In 2000 carbon dioxide (CO_2) emissions from energy use in non-domestic buildings (which includes the building related portion of industrial energy use plus commercial and public sector buildings) accounted for 20% of total UK emissions. Bottom-up modelling techniques show that energy use for heating accounts for 41% of emissions in commercial and public sector buildings, whilst lighting accounts for a further 23%. Space cooling currently accounts for only 5% of public and commercial emissions, however, where air conditioning is installed it can account for a large proportion of carbon emissions and the potential for growth in air conditioning is substantial.
- Information is also presented at the sector level. This provides a more detailed understanding of emissions that arise from different patterns of energy use that exist in different types of building activity. Overall, the retail sector accounts for 24% of emissions from public and commercial buildings, whilst emissions from the hotel and catering sector account for a further 16%. The health sector shows the highest level of emissions per unit floor area, primarily due to the high heating demand and 24 hour operation.
- An assessment of the technical and economic potential for reducing carbon emissions in public and commercial buildings is presented. This considers the effect of instantaneously implementing a wide range of energy efficient options across the building stock. Cost abatement curves give an indication of the contribution that an individual energy efficiency option could make at the national level, and the cost or saving that implementation will realise. The combined effect of implementing all options simultaneously is also assessed. This shows that the technical potential for saving carbon in UK public and commercial buildings is around 35% and that up to 20% could be achieved cost-effectively.
- Finally, the results of modelling future carbon emissions from public and commercial buildings are presented. Three scenarios are described, a reference case, which assumes current trends in the growth and the structure of the commercial and public sector persist and current rates of uptake of energy efficiency options continue. This reference case shows carbon emissions decrease by 4% between 2000 and 2010, whilst energy consumption increases by 14%. A second 'efficiency' scenario examines the effect of an enhanced rate of uptake of energy efficiency options. This shows that increased uptake rates of existing measures could reduce emissions by 16% in 2010 compared to the reference case, but the amount of additional savings beyond 2010 is more modest. Finally, a 'policy' scenario has been developed. This is based on the reference case but with the addition of actions defined in the UK Climate Change Programme[a]. This indicates that the policies set out in the Programme result in emissions from public and commercial buildings being 19% below their 1990 levels.

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[a] Climate Change: The UK Programme, DETR, November 2000, The Stationery Office.

Background

Carbon dioxide (CO_2) emissions are widely recognised as a major contributor to anthropogenic climate change. The IPCC report published in 2001 referred to the mounting evidence of an increase in global temperatures and global average sea levels, a decrease in snow and ice cover, changes in the global distribution of precipitation and increasingly frequent and intense El Niño events[1]. The report also highlights projections that globally averaged surface temperatures are set to increase by 1.4 to 5.8 °C between 1990 to 2100. Furthermore, the Royal Commission for Environmental Pollution estimates that reductions in the region of 60% relative to current day emissions would be required by 2050 to prevent atmospheric CO_2 concentrations exceeding safe limits[2].

The UK has already met the requirements of the Rio Commitment to reduce greenhouse gas emissions to 1990 levels by 2000. In further efforts to tackle climate change the UK Government has signed up to a legally binding target of a 12.5% reduction on 1990 levels of greenhouse gas emissions[b] by 2008 to 2012. This forms part of the 8% reduction agreed by the European Union at the Kyoto conference. Additionally the UK Government has set its own, more challenging goal of reducing CO_2 emissions to 20% below 1990 emissions by 2010. To meet these targets the Government and the Devolved Administrations have developed the Climate Change Programme, incorporating various measures to reduce greenhouse gas emissions[3].

In order to combat climate change it is essential to have a detailed understanding of the pattern of energy consumption and carbon emissions in the UK, the sectors involved and their potential contribution to emissions reductions. To this end DEFRA's Global Atmosphere Division has commissioned the development of a sectorally and technologically dissaggregated model of emissions from the UK buildings stock that can be used to underpin UK climate change policy. The work is also used in specific government programmes and initiatives, such as the Energy Efficiency Best Practice Programme where it is used to help target activities to maximise carbon savings, and in the development of sector scenarios for DEFRA's Market Transformation Programme.

This publication provides a summary of current knowledge of UK non-domestic buildings, their energy consumption and their carbon emissions. It also provides a detailed assessment of the technical and economic potential for carbon savings in UK public and commercial buildings and explores possible future emission scenarios. A companion report provides similar information for the domestic sector[4].

As well as being of interest to policy makers and researchers, this report should be of interest to public and commercial organisations with responsibility for managing non-domestic buildings. It should also be of interest to anyone who is involved or interested in understanding how the goal of reducing greenhouse gas emissions might be realised.

[b] This covers a basket of six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride), weighted for their global warming impact.

Acknowledgements

This publication summarises the results of work carried out under contract to the Global Atmosphere Division of the Department of Environment, Food and Rural Affairs (DEFRA). It also draws upon other work funded under the Division's Climate Change research budget, notably energy surveys and analysis undertaken by Nigel Mortimer and his team at Sheffield Hallam University and surveys and analysis of building morphology by Phil Steadman and colleagues at the Open University. Ratings data supplied by the Valuation Office Agency.

Introduction

In 1998 BRE published the "Non-Domestic Energy Fact File" [5], which provided information on the existing stock of non-domestic buildings and reported preliminary estimates of carbon emissions and energy consumption by building type. Since that report was published the state of knowledge in this field has advanced significantly. This report can therefore provide a far more comprehensive understanding of energy use and emissions from non-domestic buildings. A companion report for the housing sector has also been produced[4].

This publication provides an understanding of carbon emissions from the UK building stock based on bottom-up modelling techniques. It contains up-to-date figures on current energy consumption and carbon emissions disaggregated by sub-sector, end-use and fuel type. It provides a detailed assessment of the technical and economic potential for reducing carbon emissions in public and commercial buildings that could be realised by the application of energy efficiency options that are presently available, both for the current day and 2010. Finally, scenarios have been developed to explore possible future carbon emissions from public and commercial buildings.

A bottom-up methodology that draws on a detailed understanding of energy use in different building types and information on the characteristics of the national building stock is used. This bottom-up approach has the advantage of providing a greater degree of accuracy as data from various sources can be brought in to augment or check modelling results. Moreover, the ability to determine the emissions reduction potential at the sector and technology level is important for developing policy approaches and market barriers, respectively. The model which has been developed for this work, N-DEEM (Non-Domestic building Energy and Emissions Model), is not a fixed defined structure, but rather a looser construction which requires an understanding of issues relating to the built environment and to energy use. The advantage of this flexible framework is that it enables the many disparate sources of data to be brought together to form a comprehensive and coherent picture of energy use in UK commercial and public buildings.

A description of N-DEEM and its inputs and outputs is given in Part One.

Part Two presents energy consumption and carbon emissions for 2000. This provides an overview of emissions from the non-domestic building stock as a whole, and treats emissions from public and commercial[c] buildings in more detail.

Part Three looks at the potential that exists for reducing carbon emissions by implementing energy efficiency options in public and commercial buildings. The economic and technical potential of a wide range of energy efficiency options is quantified and presented in the form of a cost abatement curve. The total national technical and economic potential for reducing carbon emissions in public and commercial buildings is also assessed. This takes into account the effect of interactions that exist between the various energy efficient options. Sector specific carbon reduction potentials for four of the most important activity groups are also presented. An assessment of the potential for carbon savings that will remain in 2010 is also made.

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[c] Non-domestic buildings includes the energy related portion of industrial buildings as well as commercial and public sector buildings.

Projections of trends in energy use and emissions from public and commercial buildings from 2000 to 2020 are given in Part Four. Here, three scenarios are considered:

- A reference scenario, which assumes current trends in the growth and the structure of the commercial and public sector persist and current rates of uptake of energy efficiency options continue.
- An ‘efficiency’ scenario, which assumes an enhanced rate of uptake of energy efficiency options.
- A 'policy' scenario, which is based on the reference case but with the addition of actions defined in the UK Climate Change Programme[3].

Part One: Modelling Energy Use and Carbon Dioxide Emissions from Non-Domestic Buildings

1.1 Approach to Modelling

In order to provide good estimates of national carbon emissions and the potential for reducing them a bottom-up model of energy use in the UK non-domestic building stock has been developed[6]. This model is known as N-DEEM (Non-Domestic building Energy and Emissions Model). The model makes use of detailed energy use data, collected specifically for this work, covering a range of different building types and national level data on the building stock. Other data sources are also employed. To make best use of the disparate data that are available the model is not a rigidly defined structure, but a rather looser construction that allows various data to be incorporated at appropriate points in the modelling process. The additional data can be used, either to augment areas where detailed information is sparse, or to provide an additional check on the accuracy of the modelling results. In either case care needs to be taken with data that has been collected by these means, particularly as there is often no way of checking back with the third parties who may have collected the original data. An understanding of the practices and conventions used in the relevant sectors and an awareness of the purpose for which the data was collected is useful when deciding how to make the most appropriate use of data.

This bottom-up approach has the advantage of providing a greater degree of accuracy as data from various sources can be brought in to augment or check modelling results. Moreover, the ability to determine the emissions reduction potential at the sector and technology level is important for developing policy approaches and market barriers, respectively. The flexible framework of the model enables the many disparate sources of data to be brought together to form a comprehensive and coherent picture of energy use in UK commercial and public buildings.

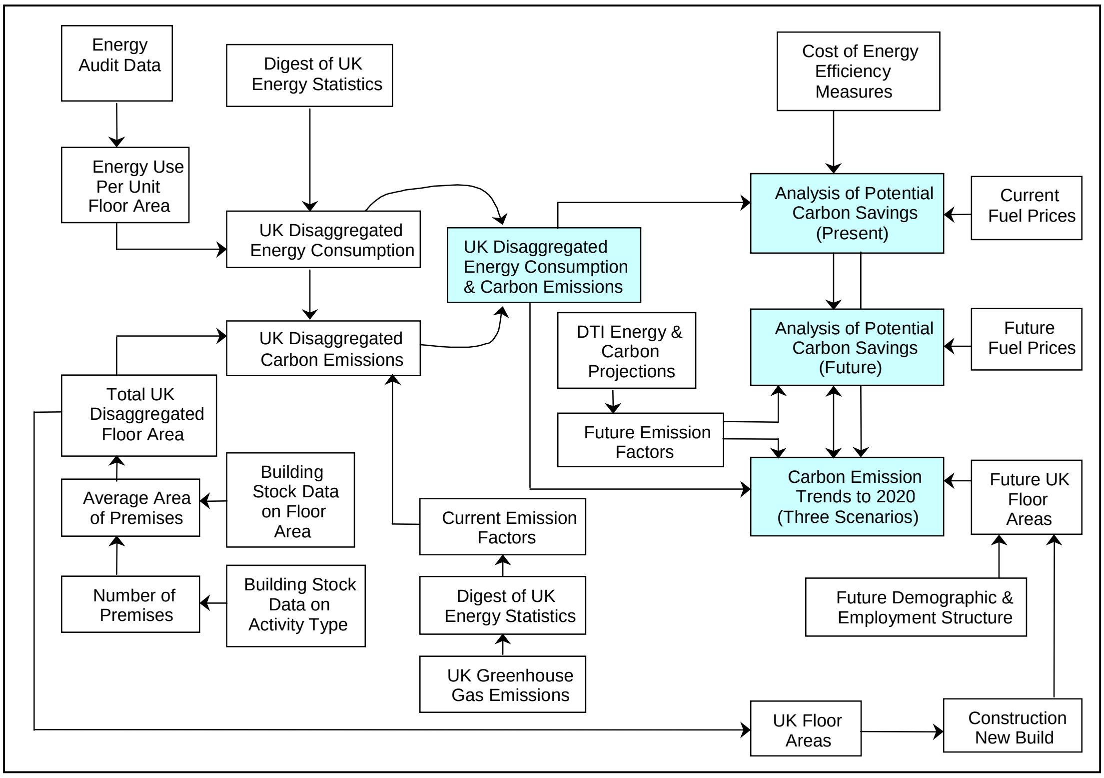
1.2 Modelling Process

The model is currently used to:

- Provide disaggregated estimates of emissions from non-domestic buildings.
- Assess the national economic and technical potential for reducing carbon emissions.
- Develop scenarios to explore likely future emissions.

These outputs and their associated modelling techniques are described in more detail in the ensuing sections of this publication. The flow chart presented in Figure 1.1 summarises these processes schematically.

Figure 1.1: Simplified diagram of N-DEEM; the highlighted boxes indicate principal outputs



The main data sources that are used in the modelling work are briefly described in the following sections:

1.3 Building Stock Data

Data collected by valuation offices gives information on all rateable non-domestic premises in England and Wales. As all premises, with the exception of crown properties, are included this gives an excellent overview of the non-domestic building stock. The Rating List records the activity type of each of the 1.7 million hereditments[d] in England and Wales. For 1.3 million of these, information about the floor area of the hereditament and details of the building it is housed in (e.g. roof and wall materials, general condition, services available, age, number of storeys etc.) plus more detailed information about the occupant's activity are also recorded. These data sources and an analysis of the UK non-domestic building stock have been described previously in the Non-Domestic Building Energy Fact File[5].

The modelling work here is based on rating data for 1994 that has been updated to 2000 using other data sources, specifically planning application data[7] and a knowledge of demolition rates for different building activities. The Valuation Office Agency has now published valuation data for 2000[e] which could be drawn upon in updates of this work.

[d] A hereditament is a unit of rateable property. It may refer to a single premise with a unique address, to more than one building on a single site, or to a part of a premise, typically where there is more than one occupier at an address or where different activities occur within the same premise.
[e] Available on the DTLR website at: http://www.planning.dtlr.gov.uk

1.4 Detailed Energy Audit Data

Detailed energy audit data covering a wide range of occupier activities and building types have been collected specifically for this project over the past nine years. The data provide information on the characteristics of the premises, the activities of its occupants, and the energy use patterns. A room by room survey records each piece of energy consuming plant and equipment and notes any energy efficient options installed or energy management practices followed. The energy use for each piece of equipment or system in the premises is then calculated and reconciled to annual fuel billing data.

The methodology for the energy audits has been developed jointly by BRE, Sheffield Hallam University[8], who carry out the surveys, and the Open University. The data are collected and analysed and undergo a validation process before being transferred into a database format. The energy audit database currently contains a detailed record of energy use in over 700 premises covering a broad range of occupant's activities and building types.

To ensure that the limited number of surveys provides the best possible estimates of emissions the surveys are targeted towards the most common types of occupant activity. The sample frame is therefore constructed with the aim of gaining a good understanding of the energy use patterns in around 80% of the stock rather than equal coverage of all activity types. Although this means accepting a lesser degree of accuracy for less common occupant activities it provides the best possible estimate that can be achieved with the survey resources available. To achieve this aim, a process of periodic assessment of the sample data in terms of distribution of energy use and proportion of stock covered has been adopted. The results are published as a 'Catalogue of Results' which serves to summarise the energy audit data[9].

1.5 Other Sources of Energy Data

This includes data collated by local authorities to monitor fuel consumption across a range of sites. Similar information for chains of retail outlets, hotels and other commercial premises are also employed wherever possible. Clearly a knowledge of the type of activity carried out by the chain is important (retail sector, star rating of hotel) so that the data can be assigned to the appropriate sector. For the government estate, data are collected for reporting purposes and this adds considerably to the robustness of the estimates for this sector.

1.6 Intermediate/Inference Data

There are some building characteristics that are needed for assessing the national potential for reducing emissions that are not directly recorded in the valuation data. In particular, information about the structure and extent of the building fabric is not recorded in the valuation data. Intermediate data are used to provide robust information on structure and fabric at the national level. Analysis of external surveys of some 34,000 addresses in four English towns[10] was used to determine typical fabric characteristics and ratios of fabric area to floor area for different activities. This was then used to infer fabric characteristics at the national level.

1.7 Modelling Thermal Interactions

An energy simulation tool has been developed that is able to determine quickly the impact of implementing packages of measures that impact on energy use for heating. It is a single zone model which uses a three-time constant (3TC) algorithm to model heat transfer[11]. This tool is able to use survey information to determine the thermal characteristics of a premise and the model can then be calibrated to the recorded energy consumption data. It is then possible to model the effect of implementing a range of measures on energy consumption. The 3TC energy simulation tool is currently used to determine the cumulative effect of implementing all cost effective and technically feasible energy efficiency measures.

1.8 Emission Factors for Delivered Energy

Emission factors for delivered energy are updated annually, principally to take account of changes to the electricity emission factor as a result of varying fuel mixes used in generation. These delivered emission factors take a wider view of the environmental impact of fuel consumption by including upstream as well as point-of-use emissions. The emission factors are primarily used to convert energy consumption into carbon emissions. Future carbon emission factors are determined from DTI's Energy Paper 68[12] and are used to produce the 2010 cost abatement curves as well as projected emissions trends to 2020. The full list of emission factors by fuel type, changes to the emission factor for electricity, and electricity projections are given in Appendix A.

1.9 Classification of Activity (Building Use) and End-Use

Within the non-domestic building stock a diverse range of activities are carried out which have a substantial impact on the energy demand patterns within them. The activity classification system developed for this work separates out all significant activity types and analyses each one separately before aggregating these to the total. Understanding how the emissions vary at the sector level is also important for climate change policy development as policy actions may be targeted at certain sectors. The classification used here is based on a combination of valuation class refined by standard industrial classification (SIC) codes where necessary.

Some 80 categories are defined, but for reporting purposes the public and commercial sectors are usually grouped together into the 10 major activity groups or sub-sectors:

- Commercial offices
- Retail
- Warehouses (excluding industrial)
- Hotels and catering
- Transport and communication (building related energy use only)
- Sport and leisure
- Education
- Health
- Government (includes local government)
- Other (includes churches, community centres etc.)

These sub-sectors are described in detail in Appendix B. The N-DEEM sub-sectors and their associated activity types correlate broadly with the Standard Industrial Classification (SIC) system[13].

It is also useful to assess emissions according to the energy demand that drives them. This is particularly important for developing the scenarios work, which is based on the demand for energy services. There are 8 major end-use categories, which are described in more detail in Appendix C. The major categories are as follows:

- Heating
- Hot water
- Lighting
- Catering
- Computing
- Cooling and ventilation
- Process
- Other

Part Two: Current Energy Consumption and Emissions

2.1 Introduction

This section gives an overview of the contribution that energy use in non-domestic buildings makes to total UK carbon emissions. A more detailed picture of emissions from commercial and public sector buildings follows. This more detailed understanding is essential for assessing the impact of energy savings technologies and techniques, and forms the basis for developing scenarios to explore future emissions.

2.2 Energy Use and Emissions from Non-Domestic Buildings

Building energy use currently accounts for 46% of total UK energy consumption, amounting to a total of 3,120 PJ and resulting in the release of 66 million tonnes of carbon into the atmosphere. Most of this energy is used in the domestic sector and a companion publication to this explores domestic sector carbon emissions in some detail[4]. Nevertheless, non-domestic buildings account for 17% of the total UK energy consumption (1,160 PJ) in 2000 and resulted in 27 million tonnes of carbon being released into the atmosphere. Figure 2.1 and Table 2.1 below give a more detailed breakdown.

Figure 2.1: Total UK delivered energy consumption (left) and related carbon emissions (right) by sector for 2000

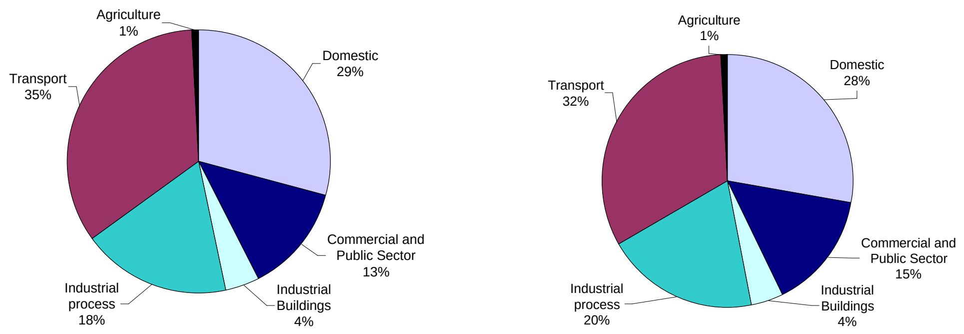
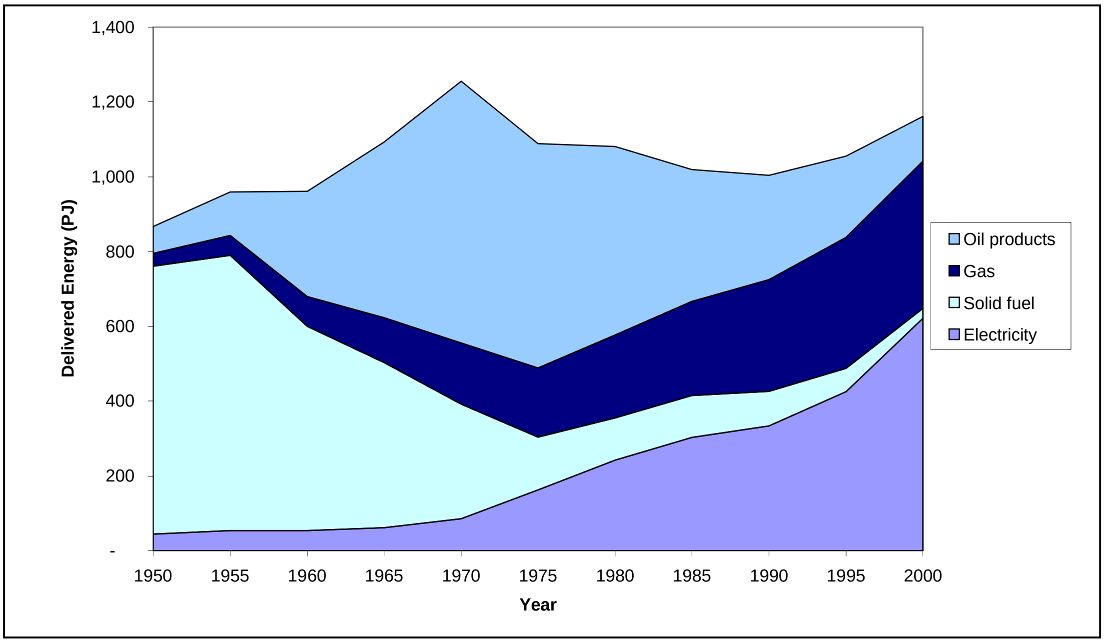


Table 2.1: Total UK delivered energy consumption and related carbon emissions by sector for 2000

Sector	Energy Consumption (PJ)	Carbon Emissions (MtC)
Domestic	1,960	39.2
Commercial and Public	880	21.2
Industrial Buildings	282	5.6
Industrial Process	1,231	27.7
Transport	2,294	46.0
Agriculture	49	1.1
Total	**6,695**	**140.9**

Figure 2.2 shows how the fuel mix used in non-domestic buildings has changed in the past. The general switch away from coal is evident; initially to oil products and then to gas as natural gas became widely available. The increase in demand for electricity throughout the period is also apparent from the graph.

Figure 2.2: Energy consumption by fuel type in non-domestic buildings: 1950 to 2000



2.3 Carbon Emissions from Commercial and Public Sector Buildings

Commercial and public sector buildings account for the majority of energy use in the UK non-domestic building stock and a more detailed analysis is presented for these sectors. In 2000 this amounted to 880 PJ of delivered energy use, and resulted in 21 million tonnes of carbon being released into the atmosphere. An understanding of where and how the energy is used in public and commercial buildings has been built up using the modelling process described in Part One of this report. Energy use and related carbon emission data are presented here, disaggregated by sub-sector, fuel and end use.

The national emissions are determined from fuel consumption patterns for some 80 different activities. These are then scaled to national stock via floor area and reconciled to national energy consumption data before being converted to carbon using delivered energy emission factors (see Appendix A). Firstly, delivered energy use per unit floor area, broken down by end use and fuel type, is derived from the detailed energy audit data and other sources[f] for each activity. National floor area is determined from valuation data except for crown properties, which includes government buildings and churches, where alternative information has been obtained. The valuation data available to this project only cover England and Wales and record the stock in 1994; 2000 valuation data have recently been published and could be used to update the analysis. To take account of changes between 1994 and 2000 the valuation data have been updated using planning application data and sub-sector demolition rates. Population statistics were used to extrapolate floor area data to Scotland and Northern Ireland. Combining energy use patterns with the national floor area gives a disaggregated

[f] These data sources are described in more detail in Part One.

estimate of national fuel consumption, which is then reconciled to national energy statistics[14]. The associated carbon emissions are calculated from delivered energy emissions factors. These take account of indirect emissions from processing and production as well as direct point of use emissions[g].

2.4 Energy Consumption and Emissions by Fuel Type

Figure 2.3 and Table 2.2 show commercial and public sector delivered energy consumption and carbon emissions broken down by fuel type. Gas consumption currently accounts for just over half of delivered energy consumption in UK public and commercial sector buildings, but only 31% of related carbon emissions (453 PJ and 6.6 MtC respectively). Electricity consumption accounts for a further 39% of delivered energy consumption and 61% of carbon emissions (341 PJ and 12.8 MtC respectively). This reflects the fact that the delivered energy emission factor for electricity is currently about twice that of gas.

Figure 2.3: UK commercial and public sector energy consumption (left) and related carbon emissions (right) by fuel type for 2000

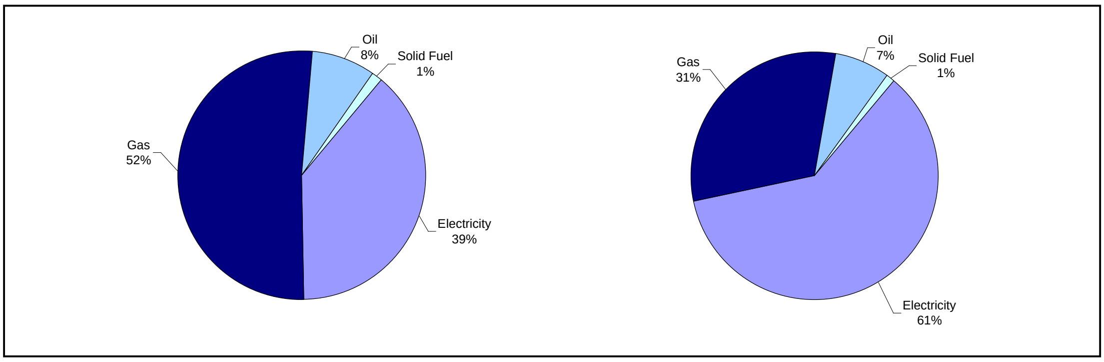


Table 2.2: UK commercial and public sector energy consumption and related carbon emissions by fuel type for 2000

Fuel Type	Energy Consumption (PJ)	Carbon Emissions (MtC)
Electricity	341	12.8
Gas	453	6.6
Oil	75	1.6
Solid Fuel	12	0.2
Total	**880**	**21.2**

2.5 Energy Consumption and Emissions by Sub-Sector

Figure 2.4 and Table 2.3 show the commercial and public sector energy consumption and carbon emissions by sub-sector[h]. The retail sub-sector accounts for the greatest proportion of energy consumption at 160 PJ, and an even greater proportion of carbon emissions at 4.8 MtC. This is because 66% of delivered energy in the retail sector is in the form of electricity, which has a higher emission factor compared to fossil fuels.

[g] See Appendix A for more information on the delivered energy emission factors used.
[h] For details about the activities included in each sub-sector see Appendix B.

Figure 2.4: UK commercial and public sector energy consumption (left) and related carbon emissions (right) by sub-sector for 2000

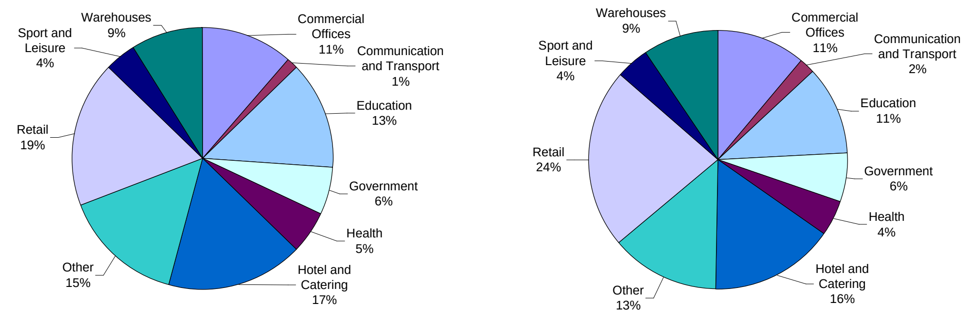


Table 2.3: UK commercial and public sector energy consumption and related carbon emissions by sub-sector for 2000

Sub-sector	Energy Consumption (PJ)	Carbon Emissions (MtC)
Commercial Offices	99	2.4
Communication and Transport	13	0.4
Education	118	2.3
Government	51	1.3
Health	45	0.9
Hotel and Catering	149	3.3
Other	132	2.9
Retail	160	4.8
Sport and Leisure	35	0.9
Warehouses	77	2.0
Total	**880**	**21.2**

2.6 Energy Consumption and Emissions by End-Use

Figure 2.5 shows delivered energy consumption and related carbon emissions, respectively, broken down by end-use[i]. Table 2.4 gives a detailed breakdown of these figures.

Overall, heating accounts for over half of all energy use in commercial and public buildings (484 PJ), but only 41% of total related carbon emissions (8.9 MtC). Lighting is the next largest energy consuming end-use accounting for 15% of commercial and public sector energy, but produces 23% of the total emissions due to electricity having a higher emission factor compared to fossil fuels. Similarly computing and cooling consume 2% and 3% of energy within the commercial and public sector, but produce 4% and 5% of the carbon emissions, respectively. As more and more electrical items are used within the commercial and public sector it is likely that the proportion of emissions that are attributed to heating will fall, although this does not mean that absolute carbon emissions from heating will fall. A comprehensive analysis of potential future carbon emissions is given in Part Four. It is also worth noting that a 1% drop in total energy consumption caused by savings in lighting will lead to a 1.6% drop in total carbon emissions. A 1% drop in energy consumption through heating savings, however, will only lead to a 0.8% drop in total carbon emissions. Although this might imply that targeting lighting would be more effective than targeting heating in order

[i] For details of the applications included in each category see Appendix C.

to reduce carbon emissions, heating consumes over half the energy consumed in the commercial and public sector, so targeting heating could reduce more carbon than lighting in absolute terms. A detailed analysis of potential energy savings is given in Part Three.

Figure 2.5: UK commercial and public sector energy consumption (left) and related carbon emissions (right) by end-use for 2000

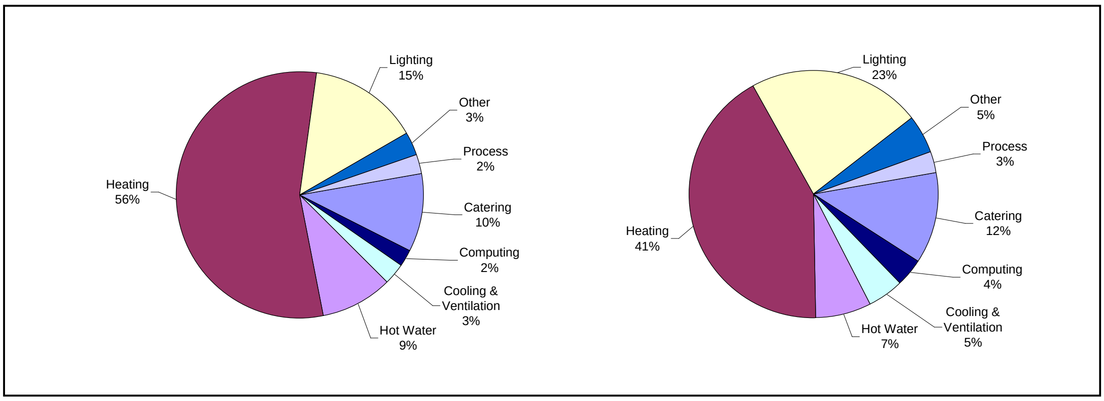


Figure 2.4: UK commercial and public sector energy consumption and related carbon emissions by end-use for 2000

End-use	Energy Consumption (PJ)	Carbon Emissions (MtC)
Catering	89	2.5
Computing	20	0.8
Cooling and Ventilation	26	1.0
Hot Water	83	1.5
Heating	484	8.9
Lighting	128	4.8
Other	28	1.0
Process	21	0.6
Total	**880**	**21.2**

2.7 Energy Consumption by Unit Floor Area

Figure 2.6 and Table 2.5 below show the energy consumption per unit floor area for each of the ten sub-sectors. Health, along with hotels and catering, shows the highest energy consumption per unit floor area at over 1.5 GJ/m^2. In these sub-sectors longer occupancy periods will lead to a higher demand for comfort heating compared to the other sub-sectors. Both sectors also require large amounts of hot water and often provide catering facilities on site. In terms of energy consumption per unit floor area, only communication and transport and retail use as much energy for lighting as they do for heating. This is consistent with many buildings within the communication and transport sub-sector having no or low heating demand as well as outdoor lighting. For retail, it is principally a reflection of the high levels of display lighting in this sub-sector. For the health sub-sector, where buildings house people that are physically inactive for long periods, higher internal temperatures will be required, which will further increase energy use per unit floor area for heating.

Figure 2.6: Commercial and public sector average energy consumption per unit floor area, broken down by end-use and sub-sector

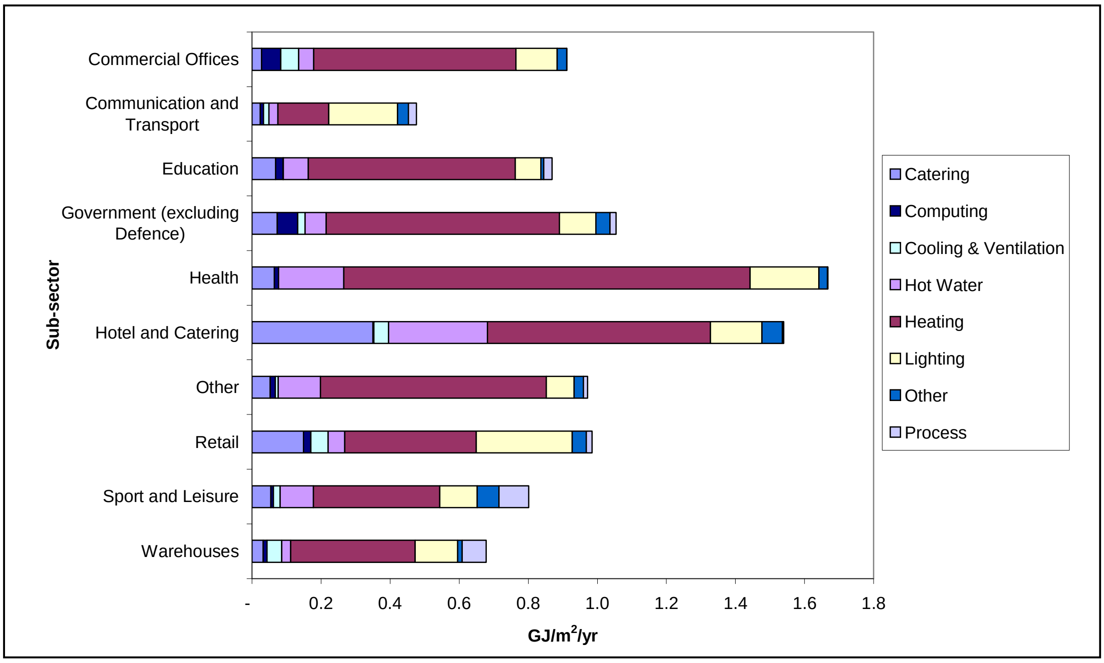


Table 2.5: Commercial and public sector energy consumption per unit floor area

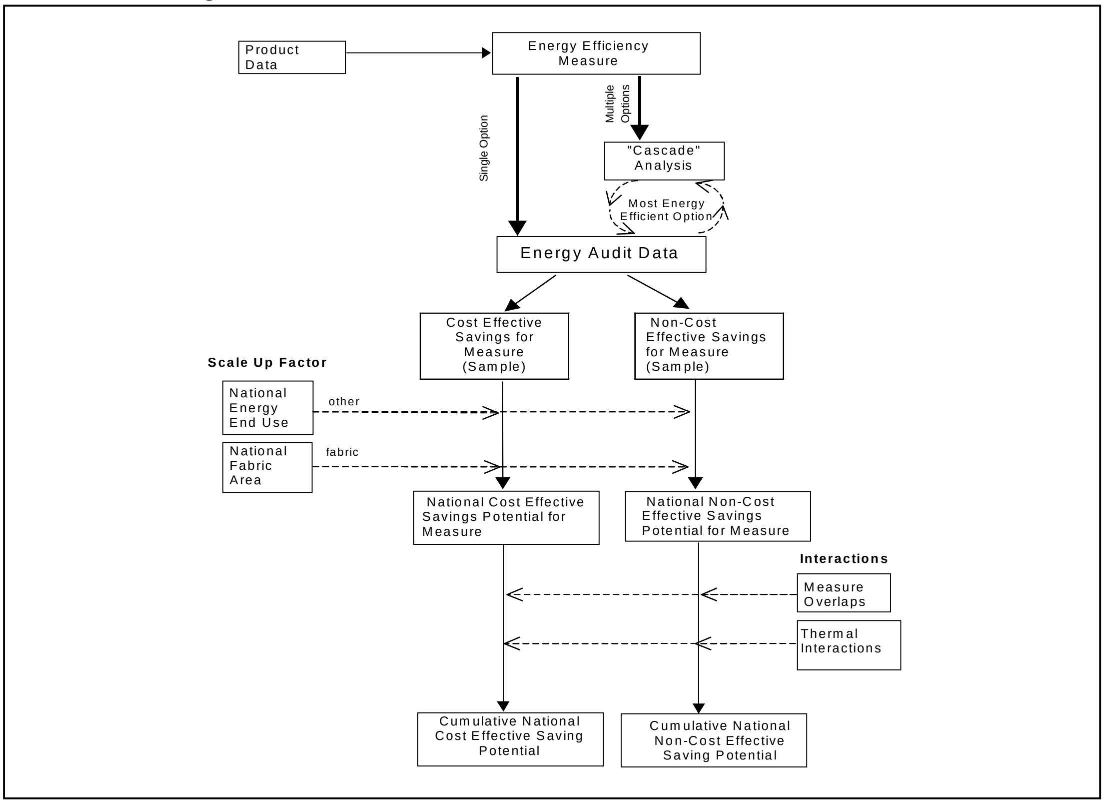
	End-use consumption per unit floor area (GJ/m^2/yr)								
Sub-Sector	Catering	Computing	Cooling and Ventilation	Hot Water	Heating	Lighting	Other	Process	**Sub-total**
Commercial Offices	0.03	0.06	0.05	0.04	0.59	0.12	0.03	0.00	**0.91**
Communication and Transport	0.02	0.01	0.02	0.03	0.15	0.20	0.03	0.02	**0.48**
Education	0.07	0.02	0.00	0.07	0.60	0.07	0.01	0.02	**0.87**
Government	0.07	0.06	0.02	0.06	0.68	0.11	0.04	0.02	**1.05**
Health	0.06	0.01	0.00	0.19	1.18	0.20	0.02	0.00	**1.67**
Hotel and Catering	0.35	0.00	0.04	0.29	0.65	0.15	0.06	0.00	**1.54**
Other	0.05	0.02	0.01	0.12	0.65	0.08	0.03	0.01	**0.97**
Retail	0.15	0.02	0.05	0.05	0.38	0.28	0.04	0.02	**0.98**
Sport and Leisure	0.05	0.01	0.02	0.10	0.37	0.11	0.06	0.09	**0.80**
Warehouses	0.03	0.01	0.04	0.03	0.36	0.12	0.01	0.07	**0.68**
Average	**0.09**	**0.02**	**0.03**	**0.10**	**0.56**	**0.14**	**0.03**	**0.03**	**1.00**

Part Three: The Economic and Technical Potential for Reducing Carbon Emissions in Commercial and Public Buildings

3.1 Introduction

This section looks at the potential that exists for reducing carbon emissions by implementing energy efficiency options in public and commercial buildings. The economic and technical potential for carbon savings is quantified for a wide range of individual energy efficiency options. This is presented in the form of a cost abatement curve which depicts total potential and cost effective energy savings as a function of discounted cost per unit of carbon saved for a range of measures. This gives an indication of where the greatest and most cost-effective energy savings exist. The total national technical and economic potential for reducing carbon emissions in public and commercial buildings is also presented. This takes into account the effect of interactions that exist between the various energy efficient options. The potential for reducing carbon emissions in four of the most important sub-sectors is examined and the potential for carbon savings that will remain in 2010 is also assessed. Figure 3.1 summarises the methodology adopted, which is described in more detail below.

Figure 3.1: Flow Chart for Assessing the Potential for Reducing Carbon Emissions in Non-Domestic Buildings



3.2 Carbon Reduction Options

A wide range of options for reducing carbon emissions were considered and data on some 1,000 individual equipment items were obtained. From this some 90[j] specific energy efficiency options were identified covering individual items of plant and equipment, enhanced levels of fabric insulation and control and energy management measures. Information on typical product cost, energy savings and lifetime were obtained for each option and data were collected for both the energy efficient measure and, where appropriate, the less efficient measure being replaced. Where an energy efficient product is a direct replacement for a standard product the marginal cost was used. This represents the additional cost (if any) of purchasing the efficient item over the standard item. Where a measure represents an additional item or measures i.e. does not replace a standard item, the full capital cost was used. For example, replacing a standard bulb with an efficient CFL bulb would incur a marginal cost; however, installing a whole new system of lighting controls would incur a capital cost. A variety of sources were used to collect such information, from manufacturers and suppliers brochures to case studies. Further relevant information was also collected including energy savings achieved and lifetimes as well as other factors that might influence the assumptions made about the application of a measure. Once the original 90 measures were sorted to exclude alternative measures[j], a total of almost 50 measures were modelled as shown in the following cost abatement curves.

It should be noted that CHP was modelled at the overall stock level and does not extend to consider instances where boilers at multiple locations are replaced by a single CHP unit. Furthermore, the sample size was not sufficient to allow analysis to be conducted at the sub-sector level. Therefore, the results for the CHP analysis are presented on the cost abatement curves for the commercial and public sectors, but not on the curves for the individual sub-sectors modelled.

The analysis presented covers established energy efficiency options that are widely available and does not extend to new and emerging technologies. Whilst it would be desirable to include more technologies it is difficult to establish meaningful costs for these. Also, the extent of their applicability may not be known. Hence the current analysis is confined to considering only established technologies.

For each energy efficiency option the instances where it could be applied in the sample were determined from detailed energy audit data, and the measure costs and savings were assessed across the range of premises covered by this data. Where a measure was judged to be applicable, the energy saving, and hence the carbon reduction that this would realise, was assessed. For items of equipment, such as energy efficient lamps, energy savings were calculated from the energy used by the standard installed item less the energy that would be consumed by the more efficient replacement. The reduction in heat loss that arises from increasing fabric insulation levels was calculated from the difference in U-value between the original and the more insulated fabric element. Whilst for controls, savings were either calculated from a knowledge of the current hours of use of the system affected and occupancy hours or typical hours of use, or were derived from case studies. Consideration of the applicability of a measure in a particular instance is important to give an accurate assessment of potential; so appropriate criteria were developed to assess the suitability of particular measures. For example, light detectors have only been applied to rooms where

[j] This number is considerably reduced in the results presented due to the inclusion of alternative measures. For example, replacing existing refrigerators with class A, class B and class C appliances have all been considered, but the results presented in the cost abatement curve consider only the most efficient option for the total potential and the most efficient cost effective option when assessing the cost-effective potential for reducing carbon emissions.

good daylight is judged to be available, based on a knowledge of the glazing area of each room.

From this the savings, as a percentage of end-use, that a measure can realise in each of the ten major sub-sectors was assessed. This was then scaled to the national level according to floor area to give the national technical potential for reducing carbon emissions.

The economic potential was determined from those instances where the measure would result in a net cost saving. Here the Net Annual Cost (NAC) has been used to determine cost effectiveness. This is a discounted cash flow calculation that considers the cost over the lifetime of the measure. A negative NAC means a measure is cost effective, and a positive NAC that it is non-cost effective. The NAC is calculated as follows:

NAC = EAC – S

Where S = annual saving from measure (£/yr)
and EAC (Equivalent Annual Cost) is:

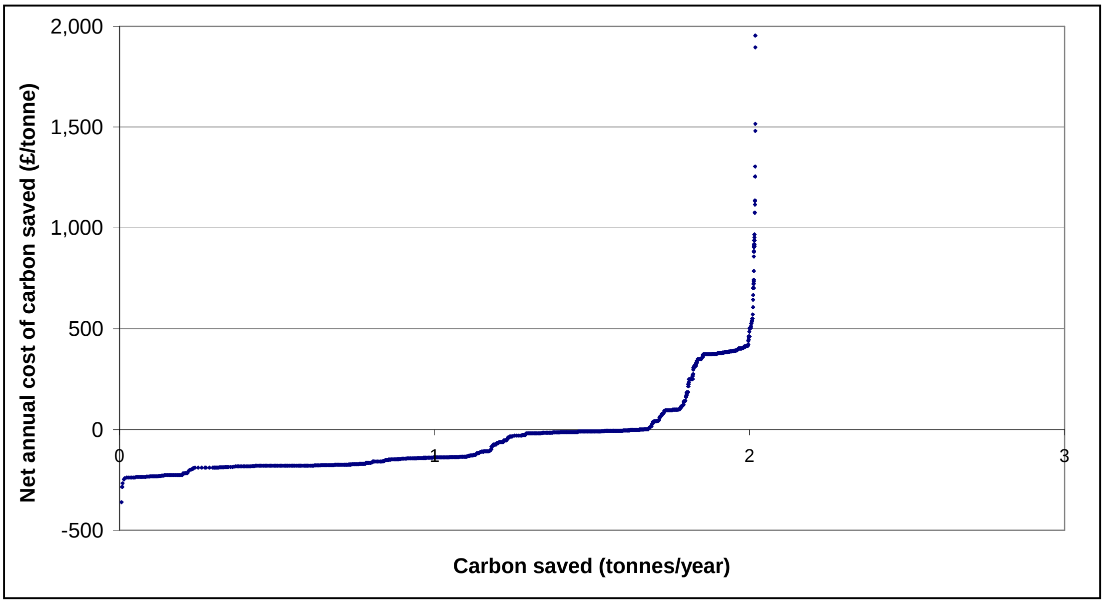
$$\text{EAC} = \frac{c \times r}{1-(1+r)^{-n}}$$

Where c = cost of the measure (marginal or capital)
r = discount rate
n = lifetime of measure

The discount rate represents the fact that commercial investors could reasonably expect returns from any monies used to purchase efficient products if invested elsewhere. To reflect the varying rates of returns that may be achieved through alternative commercial investments, a range of discount rates were considered. Discounted cash flow calculations were used to determine cost effectiveness at two different discount rates: 6%, which reflects current government criteria on investment appraisal, and 25%, which is more in line with competitive commercial situations.

Figure 3.2 demonstrates how the cost-effectiveness of an individual option (replacing 26mm fluorescent tubes with 16mm tubes) varies across specific applications. The chart plots discounted cost per tonne of carbon saved against cumulative carbon savings for all 26mm tubes identified in the sample data. This shows the variation in cost effectiveness that exists across the commercial office buildings. In the cost abatement curves that follow this range is represented by two averaged values, the average NAC/tC saved for cost effective instances and the average NAC/tC saved for non-cost effective instances.

Figure 3.2: Cost abatement curves for the sample data for the replacement of T8 fluorescent tubes with T5 fluorescent tubes[k]



Alternative energy efficient options addressing the same end use, for example replacing an existing refrigerator with a new A class or B class appliance, have been dealt with and the cost abatement curves reflect this by depicting only the carbon savings for the most efficient cost effective option, when assessing the economic potential for reducing carbon emissions. However, as each measure was modelled individually, the analysis produces a total potential carbon abatement which does not account for overlaps between different types of measures acting on the same use (for example more efficient lamps and occupancy sensors) installed in the same room. Also, the total potential carbon abatement does not account for overlaps arising because of thermal interactions (for example reduced casual gains implying greater space heating load). This issue of overlaps was dealt with separately to produce an overall saving which was generally less than the sum of the individual parts. The effect of interactions between heating and fabric measures was modelled using the thermal modelling tool described in Section 1.7. These analyses are described in more detail in Section 3.5.

3.3 Assessment of the Potential for Carbon Savings in 2010

Similar analyses were carried out to show the remaining potential for carbon savings that will exist in 2010. This takes account of the uptake of efficiency measures between 2000 and 2010, but assumes that the available options remain constant, i.e. it does not take account of the potential from new and emerging energy saving technologies. This allows a direct comparison to be made between these two points in time in terms of the potential for carbon savings and the uptake of efficiency measures.

All details of individual measures are assumed to remain constant, including costs, energy savings and lifetime. It is reasonable to use current costs since the analyses of the potential savings are carried out in present-day terms. It is certainly possible that the energy savings and lifetimes of some of the measures will improve slightly by 2010, however, it was not within the realms of this study to predict such changes.

[k] The 'steps' that are evident in the graph occur at approximately the same cost effective values for each sector and arise from a switch in the wattage of lamp being replaced.

The assessment of the potential for carbon savings in 2010 relies on the reference scenario, which has been developed to analyse future trends in emissions and is described in Part Four of this report. The 2010 cost abatement curves are based on the uptake rates in the reference scenario for commercial and public sector emissions and excludes the effect of market barriers[l]. Hence the estimates provide an optimistic view of the uptake of energy efficiency measures to 2010.

The 2010 analysis also takes into account changes in fuel prices[m] (Table 3.1) which are inclusive of the climate change levy from April 2001, carbon emission factors (Appendix A) and the impact of Enhanced Capital Allowances (ECAs) which became available on certain energy efficient products from April 2001.

ECAs for energy efficient products have been modelled for all relevant measures[n]; including lighting, motors, CHP, and variable speed drives (VSDs). Here we have modelled the effect of ECAs as a reduction in capital costs[o] and have assumed that the products eligible for these allowances will be the same in 2010[p].

Table 3.1: Fuel prices for the years 2000 and 2010

Fuel	**Year**	
	2000	**2010**
Electricity (£/GJ)	£14.1	£15.9
Gas (£/GJ)	£1.9	£2.6
Coal (£/GJ)	£1.7	£2.1
Oil (£/GJ)	£3.0	£3.0
Bottled Gas[q] (£/GJ)	£16.8	£20.2

[l] The reference scenario discussed in Part Four (Energy Consumption and Emissions from Commercial and public Sector Buildings 2000-2020) takes account of market barriers.
[m] Private communication Margaret Maier, DTI.
[n] See http://www.eca.gov.uk/index.cfm for details of products currently included.
[o] It was assumed that the value of an ECA equates to a 13% reduction in capital costs.
[p] In practice the product list for 2010 may be different as the list will be reviewed and products may be added or removed from the list to maintain effective targeting of the tax break.
[q] Estimated from market data.

3.4 National Cost Abatement Curves: 2000

The results of the cost abatement analysis for 2000 at a 6% and 25% discount rate are shown in Figures 3.3 and 3.4 below. The curves show the average Net Annual Cost (NAC) per tonne of carbon saved against the potential carbon savings for each measure. The measures are ranked by cost effectiveness and the carbon savings are plotted as a cumulative total for the UK commercial and public sector. These results indicate the potential savings from individual measures, but if added together they would substantially overestimate the national potential due to the interactions and overlaps between measures, as discussed in Section 3.2 above.

Most measures are represented twice on the graph. Where the NAC per tonne of carbon is shown as negative (i.e. below the line of the x-axis) it represents the portion of the measure that is cost effective. Where it is positive (i.e. above the line), it represents the non-cost effective portion.

Measures that incur no capital cost, such as activating energy management options on office equipment, show a maximum NAC per tonne of carbon of -£382 in 2000. The cost effectiveness of these measures is unaffected by changes to the discount rate because they have no capital cost to discount.

In contrast, for measures that do incur a marginal or capital cost the effects of changes to the discount rate are apparent. For example, for LCD (Liquid Crystal Display/flat screen) monitors the NAC per tonne of carbon increases from -£309 to -£218 as the discount rate increases from 6% to 25%. Where a measure has a particularly high capital cost relative to the energy savings the NAC per tonne of carbon is much lower, and likely to vary more considerably with the discount rate. Examples of this include boilers, CHP, double glazing and insulation.

Figure 3.3: Cost abatement curve for individual measures for the commercial and public sector in 2000 at a 6% discount rate (N.B. this does not consider interactions and overlaps)

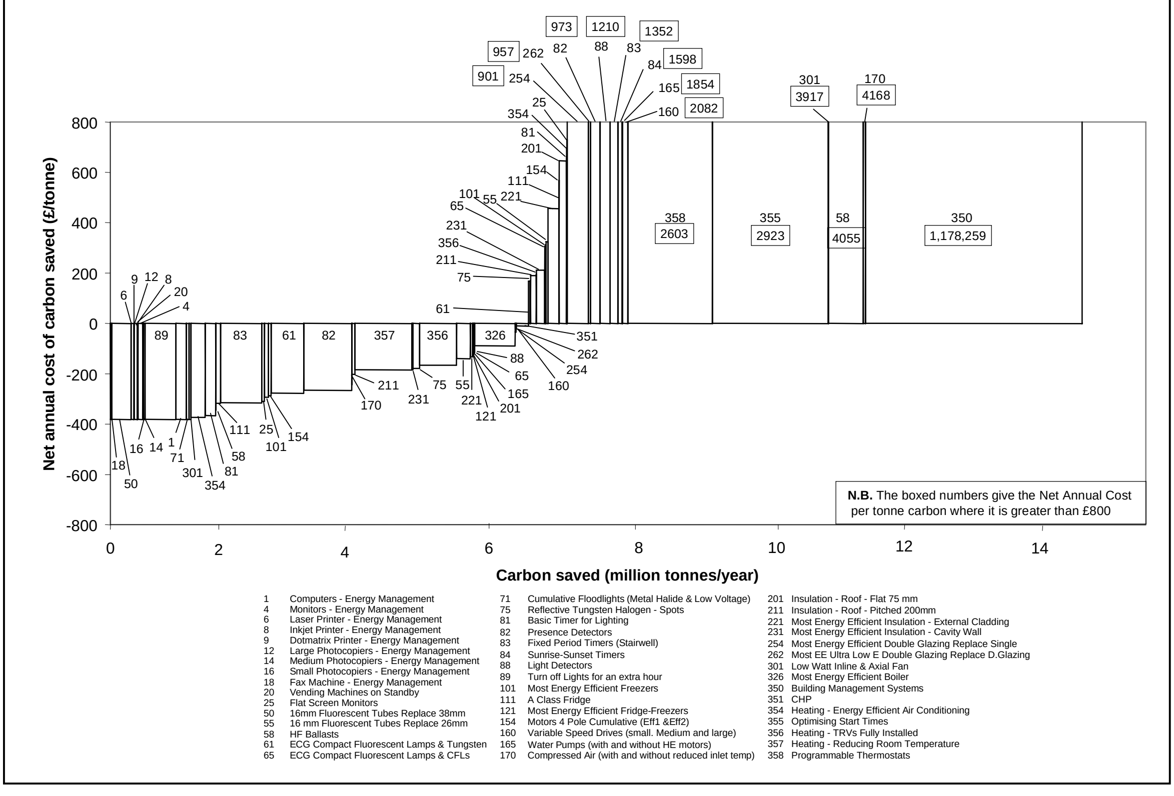
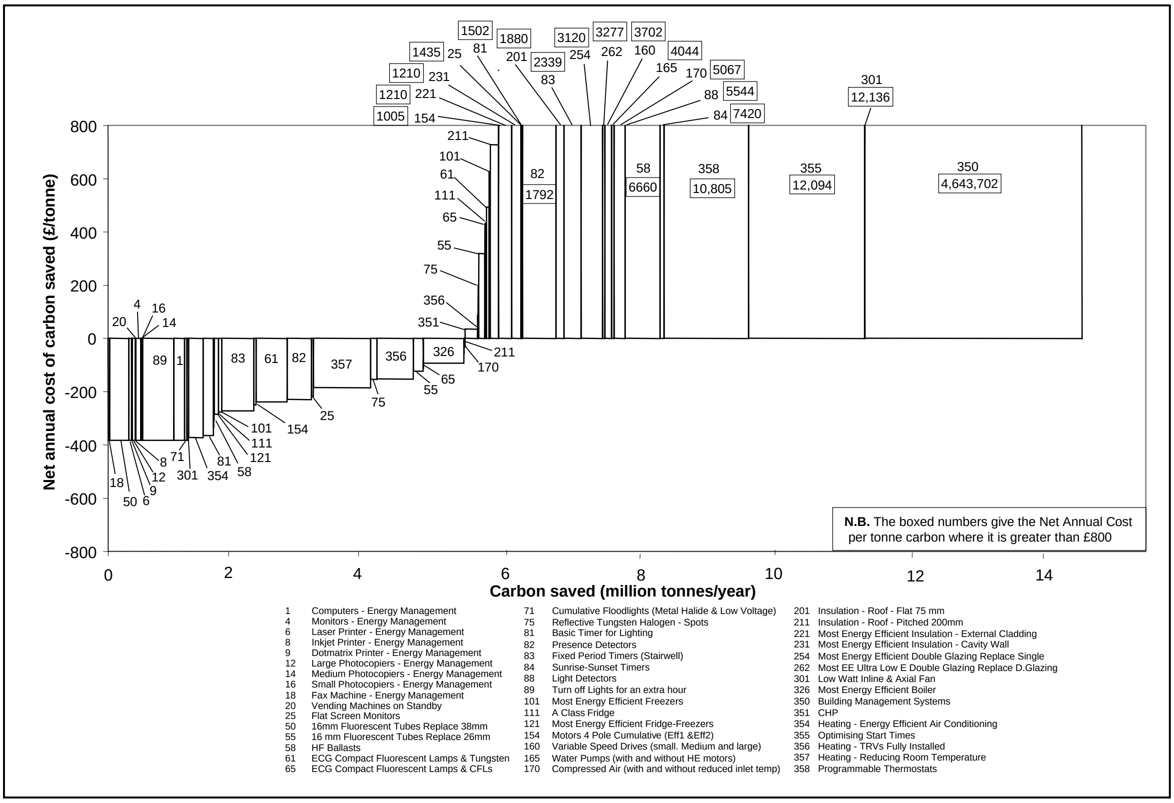


Figure 3.4: Cost abatement curve for individual measures for the commercial and public sector in 2000 at a 25% discount rate (N.B. this does not consider interactions and overlaps)



3.5 National Potential for Carbon Savings: 2000

In this section the potential for carbon savings that would arise from implementing all measures simultaneously is analysed. As discussed in Section 3.2, the measures in the cost abatement curves were modelled individually, thus not accounting for any overlaps and interactions between measures and end-uses arising because of thermal interactions. Overlaps and interactions between energy efficient measures will mean that the savings from combinations of measures may be different (usually less) than the sum of the individual parts. Overlaps have been modelled predominantly where technology measures overlap with control or management measures. For example, more efficient LCD monitors can replace standard monitors and power management features may also be employed. The LCD monitors save approximately 80% of the energy used by ordinary monitors but at a higher cost. Whilst power management is available at no extra cost and can result in a 50% energy saving. To maximise the energy saving potential, priority was given to the LCD screens as they have the greatest potential to save energy. A potential saving through good management practices is then applied to the remaining energy used.

The thermal interactions of heating and fabric measures were modelled using the thermal simulation model, 3TC (discussed in Section 1.7). Since 3TC is currently unable to model cooling interactions[r], the cumulative savings presented here will underestimate the savings for cooling. However, cooling energy use is not currently significant in most premises so the effect on the 2000 cost abatement results will be small.

[r] More efficient equipment will reduce the demand for cooling.

The cost abatement curve in Figure 3.3 shows that the 2000 technical potential for carbon savings is around 14.5 MtC, of which 6.4 MtC could be saved cost effectively at a 6% discount rate. When overlaps and interactions are taken into account, the total potential drops to 7.4 MtC, of which 4.6 MtC could be saved cost effectively (Table 3.2). At a 25% discount rate a similar drop of around 30% is observed in the cost effective savings, which decrease from 5.5 MtC (Figure 3.4) to 4.0 MtC (Table 3.2) with overlaps and interactions taken into account.

Table 3.2: Maximum potential savings achievable from the simultaneous application of all energy efficiency measures in 2000 (this accounts for overlaps and interactions)

Discount Rate	End-use	Cost Effective Potential (MtC)	Technical Potential (MtC)	% Savings Cost Effective
6%	Computing	0.44	0.45	98%
	Lighting	2.08	2.37	88%
	Refrigeration	0.15	0.16	94%
	Other	0.21	0.35	61%
	Heating	1.49	3.88	39%
	Cooling	0.23	0.23	100%
	Total	**4.60**	**7.43**	**61%**
15%	Computing	0.43	0.45	97%
	Lighting	1.87	2.37	79%
	Refrigeration	0.13	0.16	83%
	Other	0.19	0.35	55%
	Heating	1.28	3.88	33%
	Cooling	0.23	0.23	100%
	Total	**4.14**	**7.43**	**54%**
25%	Computing	0.42	0.45	94%
	Lighting	1.74	2.37	73%
	Refrigeration	0.13	0.16	80%
	Other	0.19	0.35	55%
	Heating	1.26	3.88	33%
	Cooling	0.23	0.23	100%
	Total	**3.97**	**7.43**	**52%**

Table 3.2 shows that heating measures offer the greatest technical potential for carbon savings in 2000. Only a third of these savings, however, are cost effective due to many of the fabric measures, such as double glazing and insulation, being non-cost effective in many instances. Lighting measures offer the next greatest technical potential for carbon savings and, with 80% of these being cost effective, the greatest potential for cost effective savings. A large proportion of cooling and computing measures are cost effective since most of those considered are low and no cost measures which involve choosing more efficient models (in the case of cooling) and activating energy management options (for computing).

3.6 National Cost Abatement Curves: 2010

The results of the cost abatement analysis for 2010 at a 6% and 25% discount rate are shown in Figures 3.5 and 3.6 below. As for the 2000 cost abatement curves, these results indicate the potential savings from individual measures, but if added together would substantially overestimate the national potential due to the interactions and overlaps between measures discussed in Sections 3.2 and 3.5.

In 2010, measures with no capital cost lie at -£597, compared to -£382 in 2000. This change is due to the combined effects of an increase in the price of electricity, and a decrease in the carbon emission factor for electricity.

By comparing the cost abatement curves for 2000 and 2010, it is clear that the potential for carbon savings is substantially reduced as energy saving measures are taken up in the interim. Furthermore, the change in fuel cost and the electricity emission factor between 2000 and 2010 have a considerable effect on the cost effectiveness of measures. In addition, the impact of ECAs can be seen particularly clearly for CHP; in 2000 it is typically cost effective only at a 6% discount rate, whereas in 2010 (with ECAs applied) it is cost effective at both a 6% and a 25% discount rate.

Figure 3.5: Cost abatement curve for individual measures for the commercial and public sector in 2010 at a 6% discount rate (N.B. this does not consider interactions and overlaps)

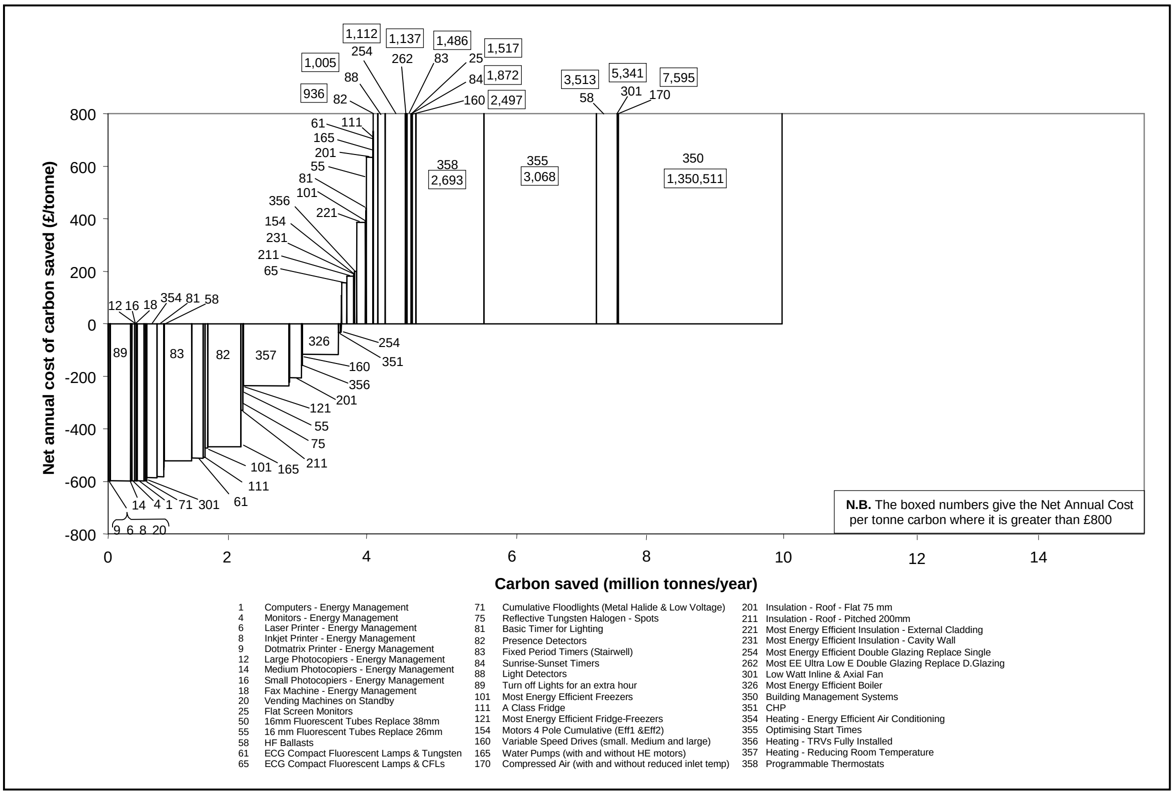
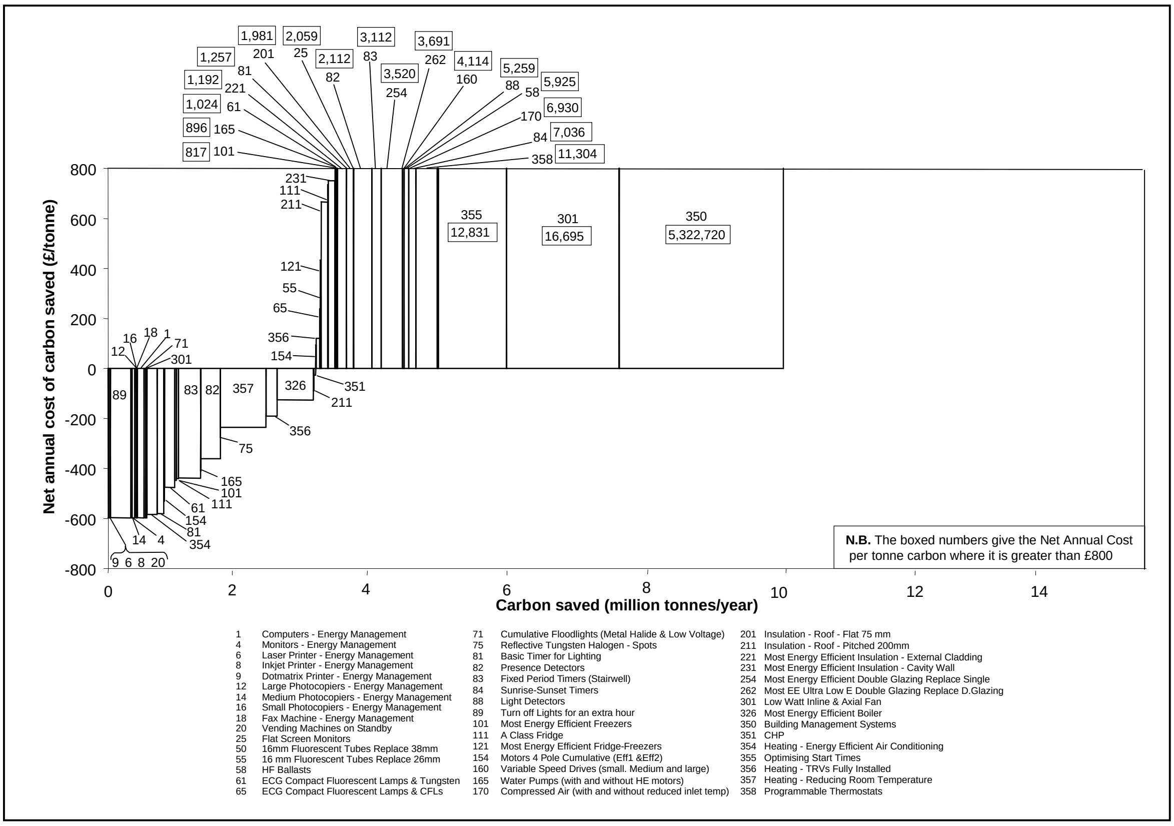


Figure 3.6: Cost abatement curve for individual measures for the commercial and public sector in 2010 at a 25% discount rate (N.B. this does not consider interactions and overlaps)



3.7 National Potential for Carbon Savings: 2010

As in Section 3.5, the potential for carbon savings that would arise from implementing all measures simultaneously is discussed here for the 2010 analysis. The results in this Section demonstrate the effects of overlaps and interactions on the potential carbon savings achievable.

The cost abatement curve for 2010 shown in Figure 3.5 shows that the technical potential for carbon reductions at a 6% discount rate is about 10.1 MtC, of which 3.6 MtC could be saved cost effectively. Taking into account overlaps and interactions, the technical potential drops to 4.7 MtC, of which 2.3 MtC could be saved cost effectively (Table 3.3). When considering a 25% discount rate the cost effective savings decrease from 3.1 MtC to 2.1 MtC when overlaps and interactions are accounted for.

Table 3.3: Maximum potential savings achievable from the simultaneous application of all energy efficiency measures in 2010 (this accounts for overlaps and interactions)

Discount Rate	End-use	Cost Effective Potential (MtC)	Technical Potential (MtC)	% Savings Cost Effective
6%	Computing	0.30	0.30	98%
	Lighting	0.65	0.76	86%
	Refrigeration	0.08	0.09	89%
	Other	0.11	0.20	54%
	Heating	0.95	3.16	30%
	Cooling	0.16	0.16	100%
	Total	**2.25**	**4.67**	**47%**
15%	Computing	0.30	0.30	98%
	Lighting	0.59	0.76	78%
	Refrigeration	0.08	0.09	84%
	Other	0.11	0.20	56%
	Heating	0.93	3.16	30%
	Cooling	0.16	0.16	100%
	Total	**2.17**	**4.67**	**45%**
25%	Computing	0.30	0.30	98%
	Lighting	0.53	0.76	69%
	Refrigeration	0.07	0.09	71%
	Other	0.10	0.20	51%
	Heating	0.91	3.16	29%
	Cooling	0.16	0.16	100%
	Total	**2.07**	**4.67**	**43%**

The breakdown of savings by end-use for 2010 (Table 3.3) shows a similar pattern to those for 2000 (Section 3.5), only with reduced savings overall. Lighting still has a high potential to save carbon, but the figure has been greatly reduced due to the relatively quick uptake of efficient lighting measures and a high replacement rate due to the shorter life span of lighting equipment compared to other end-uses. Conversely, the potential for carbon savings from heating is only slightly lower than in 2000 (Table 3.2). This is due to a relatively low turnover in the existing stock of boilers and low uptake rates of fabric measures. The potential for carbon savings from computing has decreased by around a third due to the uptake of LCD monitors and an increasing emphasis on power management techniques.

3.8 Cost Abatement Curves and Carbon Savings for the Sub-Sectors

Four sub-sectors were analysed in detail; commercial offices, retail, hotels and catering, and sport and leisure[s]. Together they account for just over half of current commercial and public sector energy consumption in the UK. Figures 3.7 to 3.10 below depict the cost abatement curves for each of the sub-sectors at a 6% discount rate for 2000.

The curves show that retail has the greatest technical potential for carbon savings, followed by hotels and catering, commercial offices and sport and leisure. This is consistent with their relative energy consumptions. Aside from the size of the potential savings, the main differences between the curves for each sub-sector lie in the breakdown of end-uses from which the cost effective carbon savings may be achieved. For commercial offices a high proportion of cost effective savings are derived from office equipment. For retail a large amount comes from lighting and lighting controls. This is also true for hotels and catering where heating controls also form part of the cost effective savings.

[s] These four sub-sectors were analysed since the thermal modelling tool, 3TC, has the capability to model thermal interactions in detail for these activities.

Figure 3.7: Cost abatement curve for individual measures for the commercial offices sub-sector in 2000 at a 6% discount rate (N.B. this does not consider interactions and overlaps)

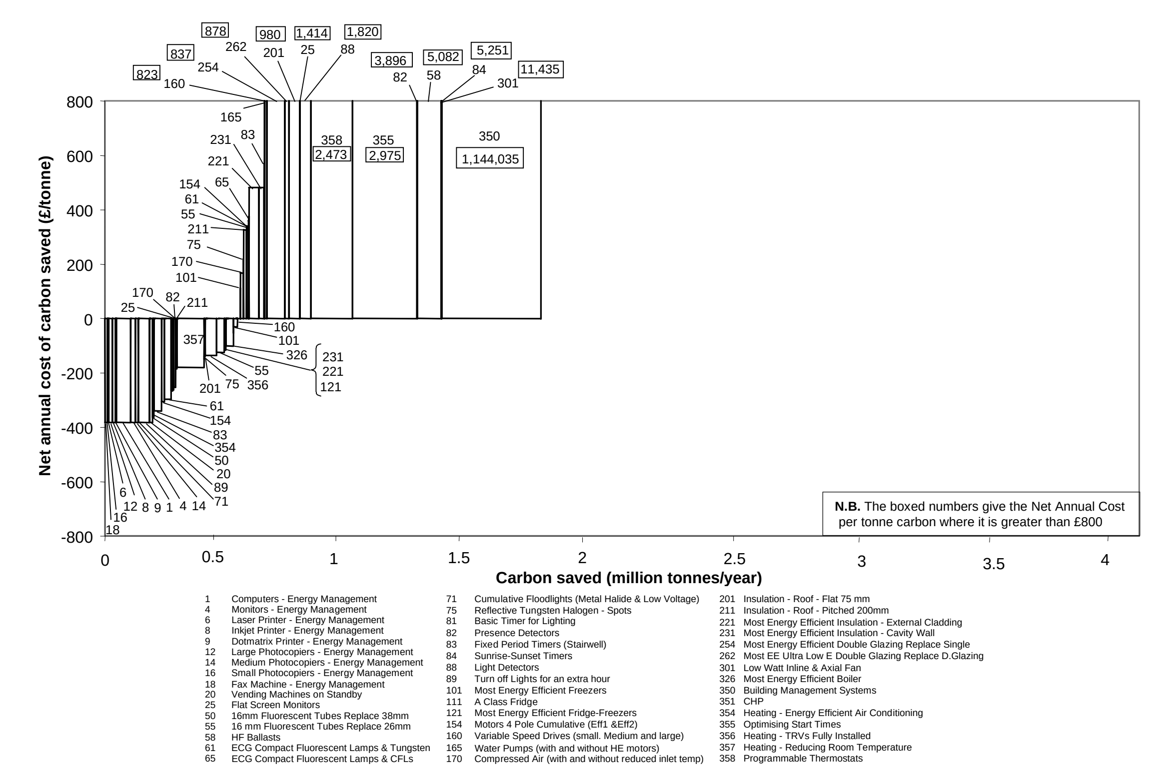


Figure 3.8: Cost abatement curve for individual measures for the retail sub-sector in 2000 at a 6% discount rate (N.B. this does not consider interactions and overlaps)

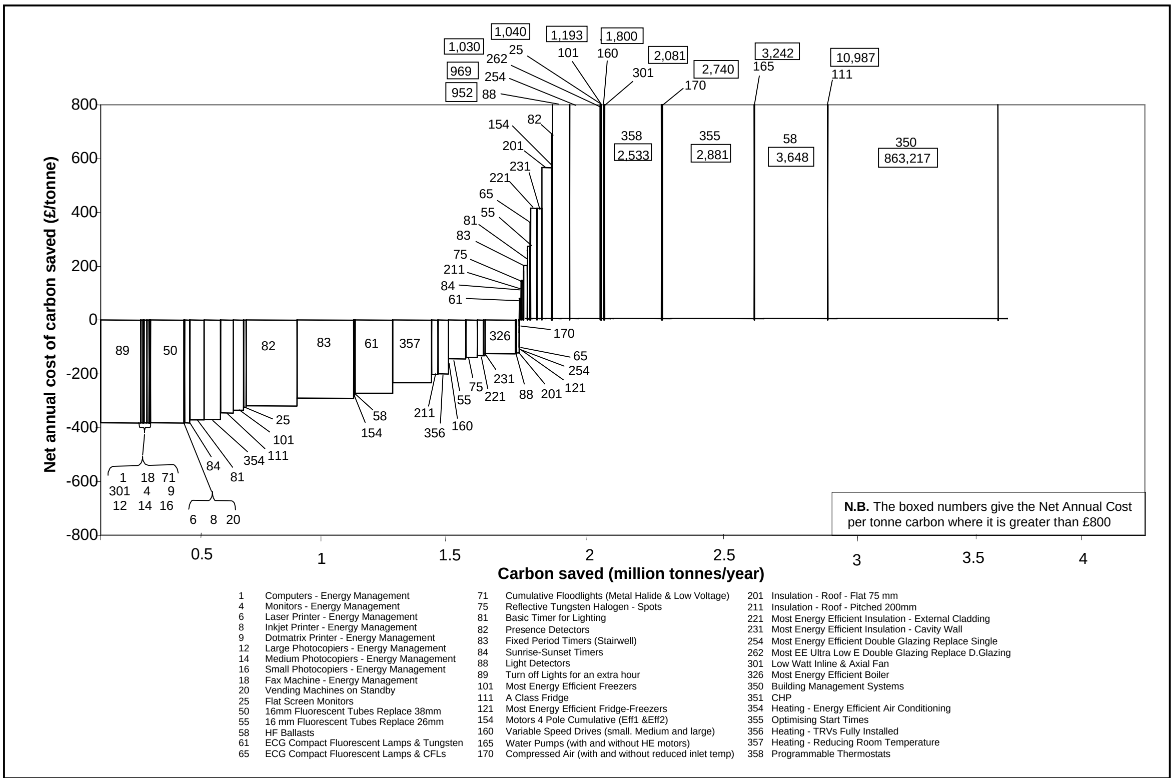


Figure 3.9: Cost abatement curve for individual measures for the hotels and catering sub-sector in 2000 at a 6% discount rate (N.B. this does not consider interactions and overlaps)

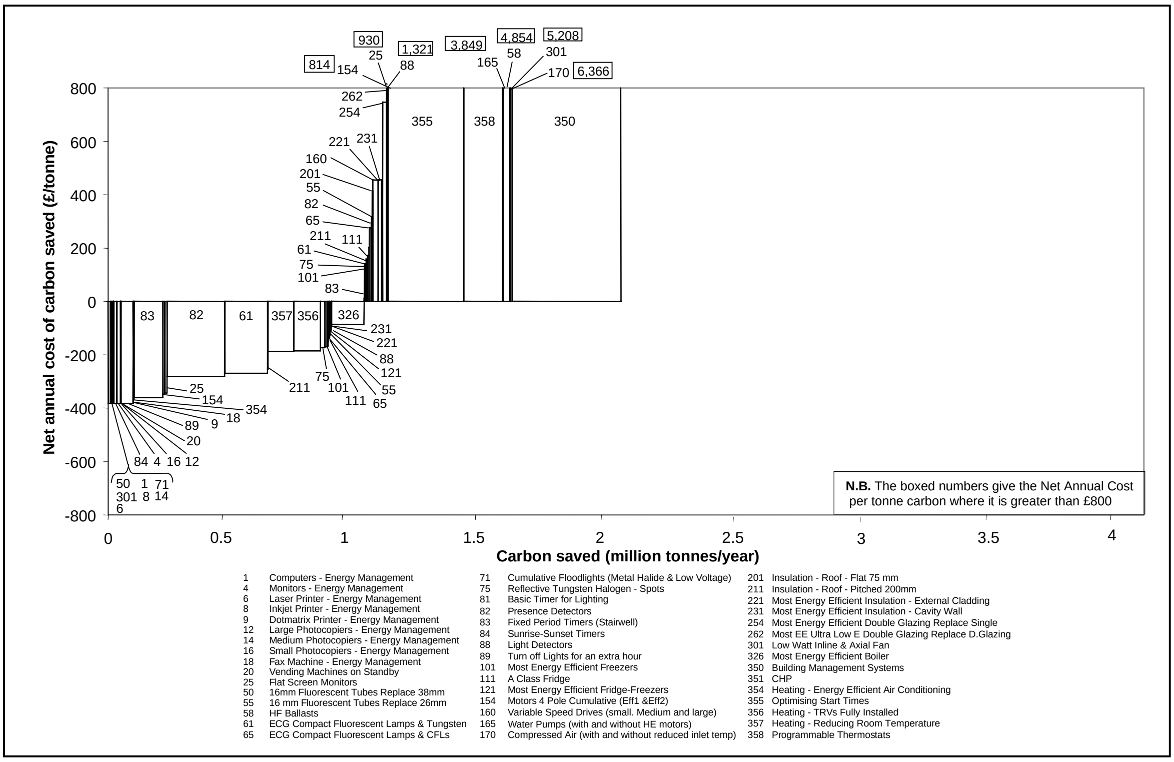
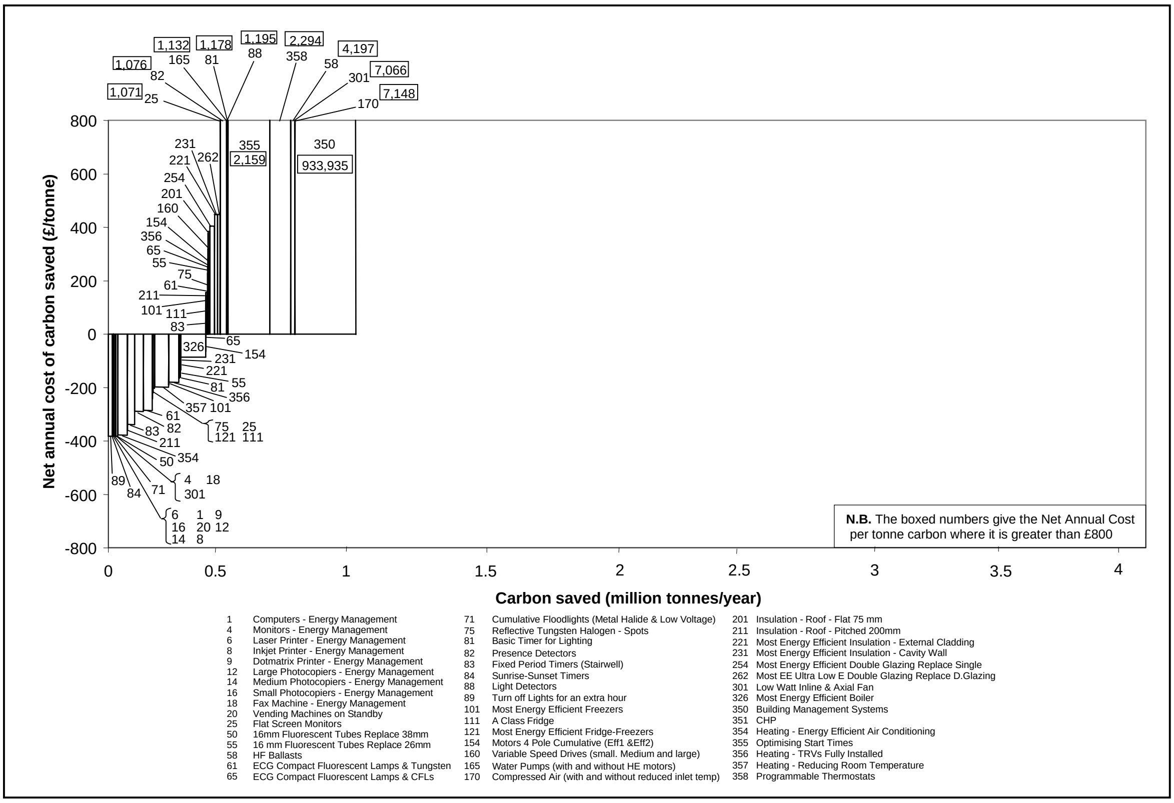


Figure 3.10: Cost abatement curve for individual measures for the sports and leisure sub-sector in 2000 at a 6% discount rate (N.B. this does not consider interactions and overlaps)



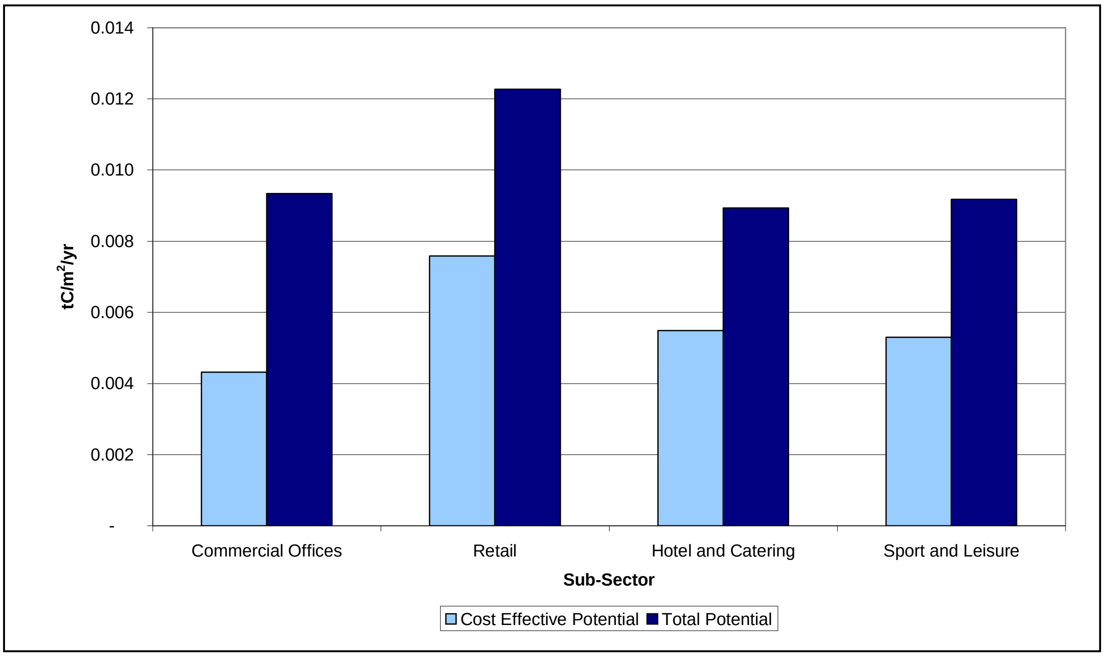
The potential for carbon savings that would arise from implementing all cost effective measures simultaneously for each of the four sub-sectors was also analysed, allowing for overlaps between measures and thermal interactions. The results are shown in Table 3.4, which shows again that the highest carbon savings for computing are likely to be in the commercial offices and retail sub-sectors. The potential for reducing carbon emissions from lighting is highest in retail due to the high levels of display lighting. There is also a high potential for lighting savings in the hotel and catering sector, of which 92% is cost effective. The highest proportion of cost effective heating measures comes from the hotel and catering, and sport and leisure sub-sectors due to their relatively high levels of heating demand.

Table 3.4: Cumulative results by end-use and discount rate for the 2000 cost abatement analysis by sub-sector (this accounts for overlaps and interactions)

Sub-sector	Discount Rate	End-use	Cost Effective Potential (MtC)	Technical Potential (MtC)	% Savings Cost Effective
Commercial Offices	6%	Computing	0.12	0.12	99%
		Lighting	0.14	0.28	51%
		Refrigeration	0.00	0.00	62%
		Other	0.08	0.10	76%
		Heating	0.12	0.51	24%
		Cooling	0.01	0.01	100%
		Total	**0.47**	**1.02**	**46%**
Retail	6%	Computing	0.11	0.11	98%
		Lighting	0.70	0.97	73%
		Refrigeration	0.10	0.10	99%
		Other	0.02	0.04	58%
		Heating	0.23	0.70	32%
		Cooling	0.07	0.07	100%
		Total	**1.23**	**1.99**	**61%**
Hotel and Catering	6%	Computing	0.00	0.00	99%
		Lighting	0.31	0.34	92%
		Refrigeration	0.01	0.02	77%
		Other	0.02	0.05	33%
		Heating	0.18	0.45	40%
		Cooling	0.00	0.00	100%
		Total	**0.53**	**0.87**	**61%**
Sport and Leisure	6%	Computing	0.01	0.01	96%
		Lighting	0.07	0.09	74%
		Refrigeration	0.00	0.00	87%
		Other	0.00	0.00	75%
		Heating	0.10	0.25	42%
		Cooling	0.04	0.04	100%
		Total	**0.23**	**0.40**	**58%**

By observing the results on a unit area basis the contribution of the comparative size of each sub-sector can be removed from the analysis. Figure 3.11 shows the potential carbon savings per unit area for the sub-sectors taking into account interactions and overlaps. The graph shows that although commercial offices have a relatively high absolute value of cost effective carbon savings, these savings per unit floor area are actually the lowest of the four sub-sectors. Only 46% of the potential carbon savings available may be achieved cost effectively in the commercial offices sub-sector.

Figure 3.11: Potential carbon savings by unit floor area for each of the four sub-sectors (this considers overlaps and interactions)



Part Four: Energy Consumption and Emissions from Commercial and Public Sector Buildings 2000-2020

4.1 Introduction

This section describes future trends in energy consumption and carbon emissions in the UK commercial and public sector building stock to 2020. A bottom-up, technological approach is used which allows the results to be disaggregated by sub-sector, fuel type and end-use. This allows for a greater understanding of changes that are occurring at the level of sub-sector and end-use.

Three scenarios were modelled; a reference scenario, an efficiency scenario and a policy scenario. The reference scenario assumes current rates of improvement in energy efficiency due to take-up of more efficient technologies, current rates of sector growth and increases in the demand for specific end-use services (where they are not already saturated) continue in the future. The reference scenario implicitly assumes current Government policy actions and initiatives, such as the EEBPP[t] aimed at improving energy efficiency and reducing carbon emissions, continue. For the first time efficiency and policy scenarios have also been developed. The efficiency scenario assumes an enhanced rate of improvement in energy efficiency where all cost-effective measures are taken up at an enhanced rate. The policy scenario is a perturbation of the reference case, including carbon savings from the actions proposed in the UK Climate Change Programme[3].

Future energy consumption from public and commercial buildings is determined using the following factors:

- Changes in the structure of the commercial and public sector (sub-sector floor area trends).
- Future demands for energy services.
- Increased take up of energy efficient technologies (improvements to energy efficiency).

The emissions associated with projected electricity use in future years were estimated using emission factors derived from DTI top-down GDP growth based energy projections[12] (Appendix A). The DTI projections include the current Government targets for renewable energy and CHP generation and hence these assumptions, insofar as they relate to the electricity emission factor, are embedded in the bottom-up scenarios described here.

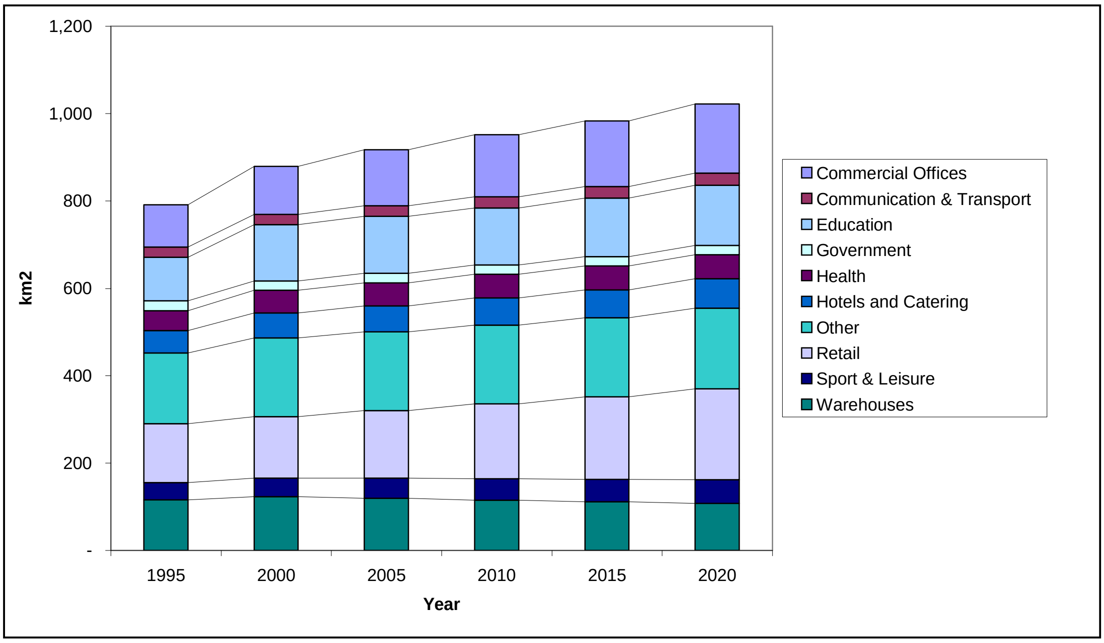
Currently available technologies have been modelled to provide an estimate of what might happen in the future. In reality, however, it is likely that there would be some influence of new technologies on future carbon emissions. Additionally, it is important to remember, as with any projections, that these are estimates and future emissions may not necessarily follow these trends.

[t] Energy Efficiency Best Practice Programme.

4.2 Sub-Sector Floor Area Trends

As floor space is a major determinant of demand for energy services the scenarios are based on sub-sectoral projections of floor area. These projections were based on current trends in new build and demolitions rates, moderated according to expected changes in demographic size, structure, and distribution of the workforce. Figure 4.1 below summarises the trends in sub-sectoral floor areas and shows an overall growth in commercial and public sector floor area. Much of this growth is due to increasing floor areas in the retail and commercial offices sub-sectors as these activities continue to grow. The hotels and catering, and sport and leisure sub-sectors also show relatively large increases and reflect expected growth in these areas. The education sub-sector has shown a considerable increase in recent years, mainly due to continued growth in the higher and further education sector. However floor areas could stabilise at around current levels due to the number of school age children decreasing slightly and therefore offsetting the more modest growth rates for further and higher education in the future.

Figure 4.1: Floor area trends by sub-sector



4.3 Changes in the Demand for Energy Services

For end-uses where demand per unit floor area is not saturated, the expected change in demand was modelled. Increased demand for air conditioning, office equipment and the 'other' category of end-uses were included in the model. These changes were modelled at the sub-sector level to give a detailed account of where particular changes are likely to be occurring.

The demand per unit floor area for all other energy services (heating, lighting etc.) is assumed to remain constant. Extended opening times were introduced to the retail sub-sector to reflect the general trend towards longer opening hours on weekday evenings and on Sundays.

4.4 Uptake of Energy Efficiency Measures

Energy efficiency uptake refers to the efficiency improvements in each of the end-uses, and the replacement within the stock of standard products and items with their more efficient counterparts. The rate of uptake in future years is built up from projecting current rates of the uptake of energy efficient products. This is achieved by fitting an S-curve to market penetration data[u] [15]. The S-curve shows a relatively slow uptake rate as a product first enters the market, followed by a much faster rate of uptake as it reaches the mass market, slowing down again as market saturation is approached. The following equation is used to define the S curve:

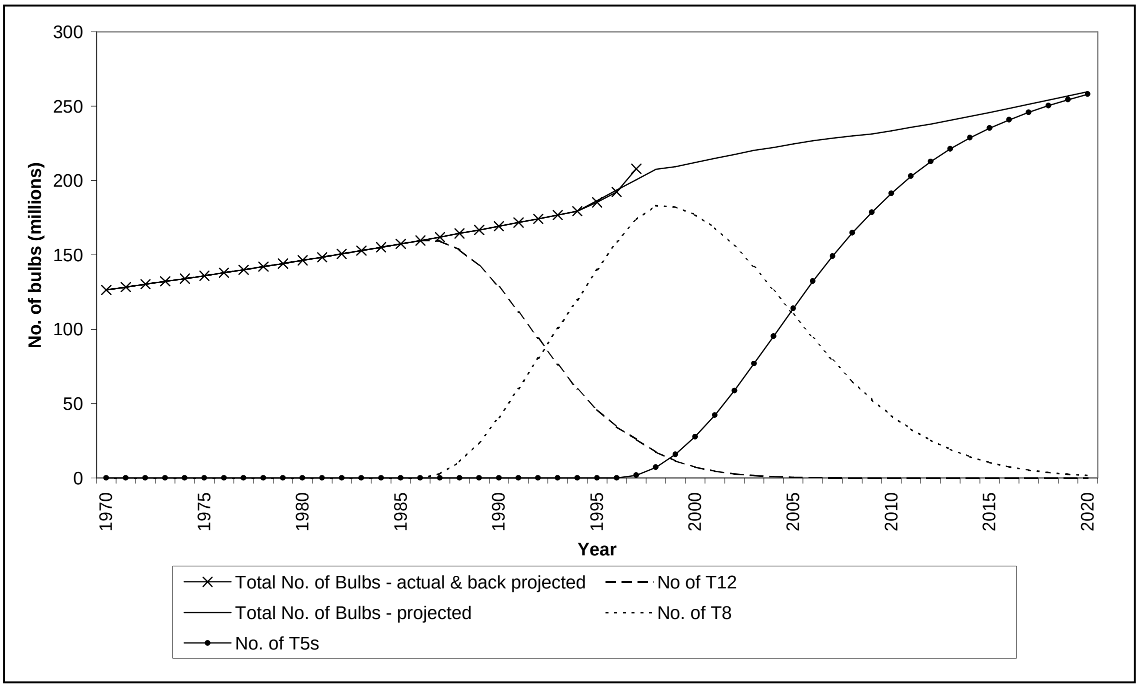
$$L = S\,[\,1 - \exp\,(\,-k\,(\,t - t_0\,)^2\,)\,]$$

Where:

- L - Ownership level in a particular year (percentage)
- S - Expected saturation level (percentage)
- t - Time (year analysed)
- t_0 - Time (product/measure introduced to market)
- k - Constant that describes the rate of uptake in the market

Where ownership or sales data were available, S-curves were constructed to describe the uptake for specific energy efficiency options. Figure 4.2 shows sample S-curves for the increasing take up of more efficient fluorescent lighting. This shows the gradual growth in the total number of bulbs installed over time and how this is distributed between the different lamp types. 38mm fluorescent tubes (T12) are the least efficient which have already been largely replaced by more efficient 26mm tubes (T8). However, 16mm tubes (T5) have entered the market more recently, and projecting an S-curve based on this data indicates that 16mm tubes will be the norm in 2020.

Figure 4.2: Substitution between T12, T8 and T5 fluorescent tubes



u An S-curve describes the pattern of uptake of a new measure, which generally forms an 'S' shape

Reliable ownership and sales data for the commercial and public sector are sparse. In most cases, therefore, S-curves had to be constructed based on a knowledge of the current level of ownership, the market potential for the measure, and an assumed market penetration rate.

Where reliable market data was unavailable the maximum feasible cost effective uptake of efficiency measures was used. Market barriers were applied to these uptake rates according to each sub-sector, so that the uptake of each measure was limited by a percentage value specific to each sub-sector[v]. Since the market barriers are integral to the reference scenario, they are also implicitly considered in the policy scenario since this is based on a reduction in emissions from the reference scenario. Market barriers were removed in the efficiency scenario to allow for maximum uptake of efficient measures.

The impact of improvements to the building envelope on heating demand was modelled using the 3TC energy simulation tool (discussed in Section 1.7). These improvements occur mainly as a result of improvements to the building fabric (such as insulation), which are predominantly linked to the legislation in Part L of the Building Regulations[w] [16].

4.5 Reference Scenario

The reference scenario depicts a possible trend in consumption and emissions assuming current trends and policy continue. This includes those policies covered in the DTI's top down projections[12]; the continuation of the Energy Efficiency Best Practice Programme at current levels, the impact of the climate change levy, that the 10% renewables target is met, and that the targets for the increase in CHP are met. The uptake of efficient measures is assumed to continue in line with past rates and under the influence of market barriers. The reference case only considers technologies that are currently available and therefore does not explicitly take account of potential future technological developments.

Figure 4.3 shows the projected course of energy consumption for the UK commercial and public sector to 2020 for the reference scenario. Energy consumption increases by around 26% to 1,100 PJ between 2000 and 2020 (Table 4.1). Under this scenario energy consumption is set to rise at a steady pace to 2020, although there is a very slight decrease in the rate of change after 2005.

The carbon emission projections depicted in Figure 4.4 show that under the reference scenario emissions decrease between 2000 and 2005, followed by a continual increase to 2020, by which time emissions are only around 0.2% below 1990 levels. This pattern of change is due to the influence of the projected electricity emission factor, which is set to decrease to 2010 and subsequently increase to 2020.

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[v] These market barrier factors have been determined by BRECSU sector experts. They take account of the factors (financial, institutional or lack of information) that prevent energy efficient options being adopted. These market barrier factors also take into account factors that will have a positive effect on the uptake of energy efficiency measures.

[w] The building regulations primarily impact on the building fabric and the effect of provisions that act on other end uses are small relative to heating and so have been ignored here.

Figure 4.3: Projections of energy consumption in the UK commercial and public sector for the reference scenario

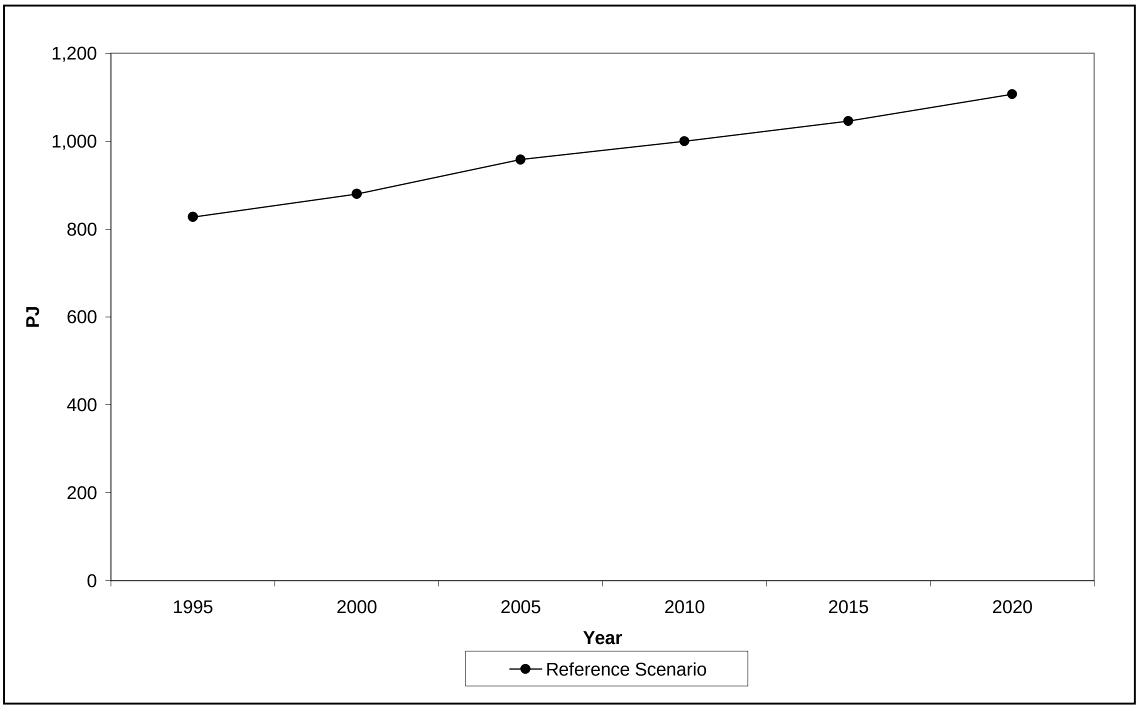


Figure 4.4: Projections of carbon emissions in the UK commercial and public sector for the reference scenario

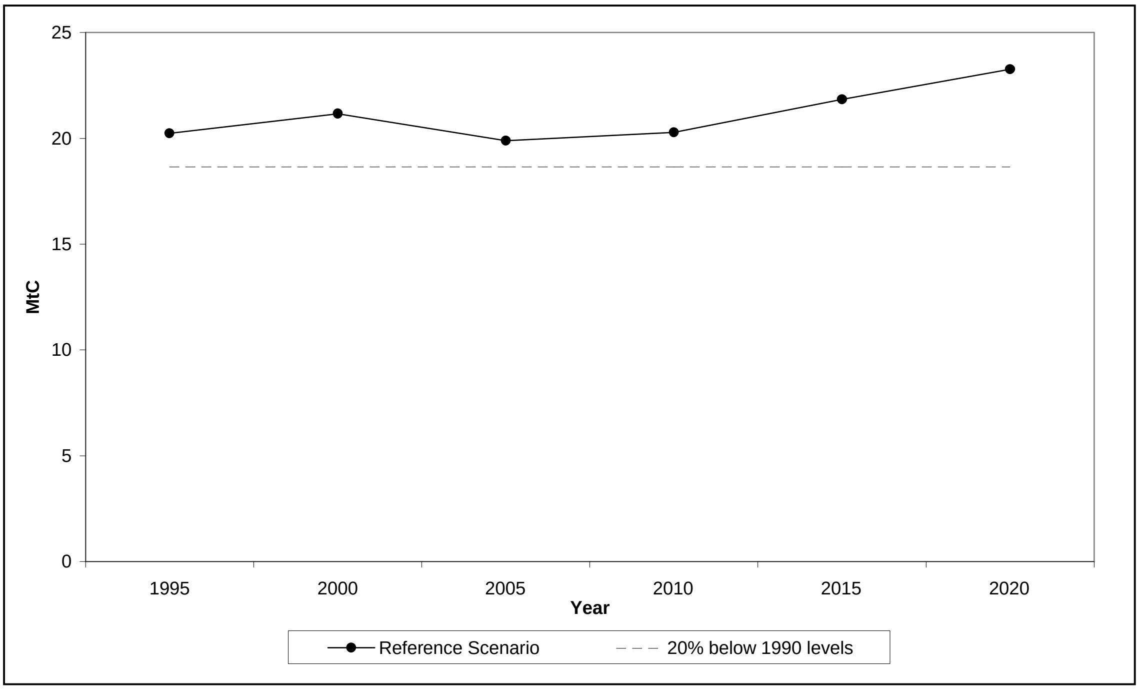
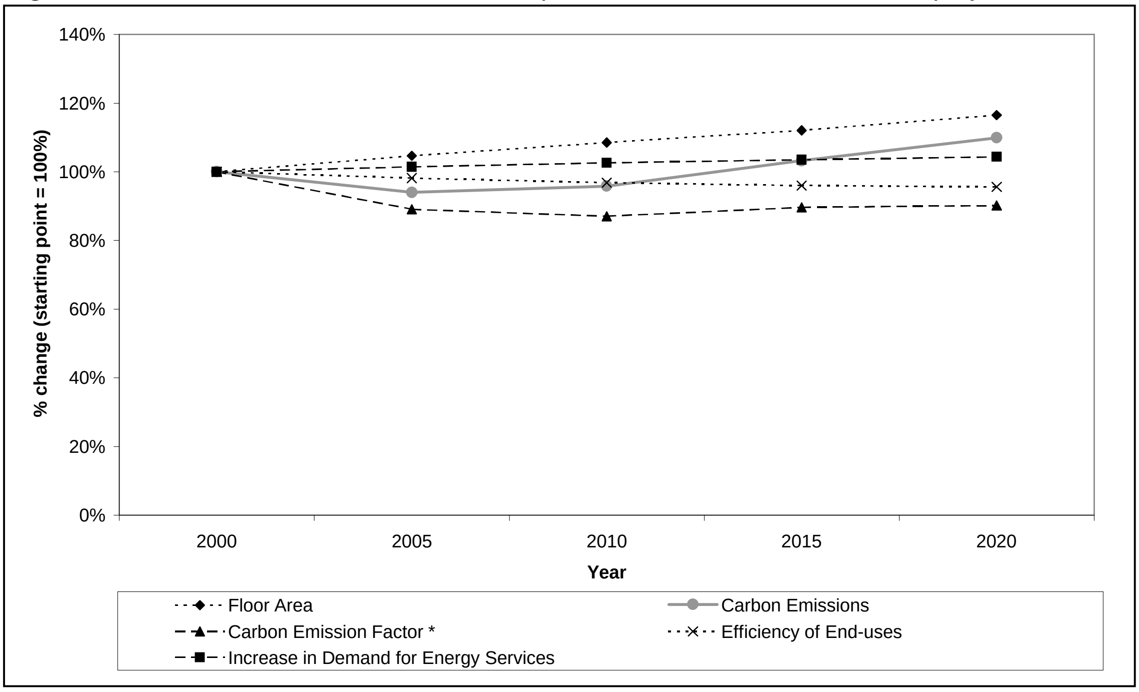


Table 4.1: Changes in floor area, energy consumption and carbon emissions for the reference scenario

Year	Floor Area (% change from 2000)	Energy Consumption (% change from 2000)	Carbon Emissions (% change from 2000)
2000	0%	0%	0%
2005	5%	9%	-6%
2010	9%	14%	-4%
2015	12%	19%	3%
2020	17%	26%	10%

Figure 4.5 below shows the contribution of each of the major model inputs to the final projections of carbon emissions as a percentage change from 2000. It is clear that the increases in floor area and demand for services push the carbon emissions up, whilst the improvements in efficiency serve to counteract this to some extent. The influence of the carbon emission factor on the total carbon emissions is also clear, with the carbon emissions trend following a similar pattern to the emission factor trend to 2010. After 2010, however, carbon emissions increase as both floor area and the emission factor increase.

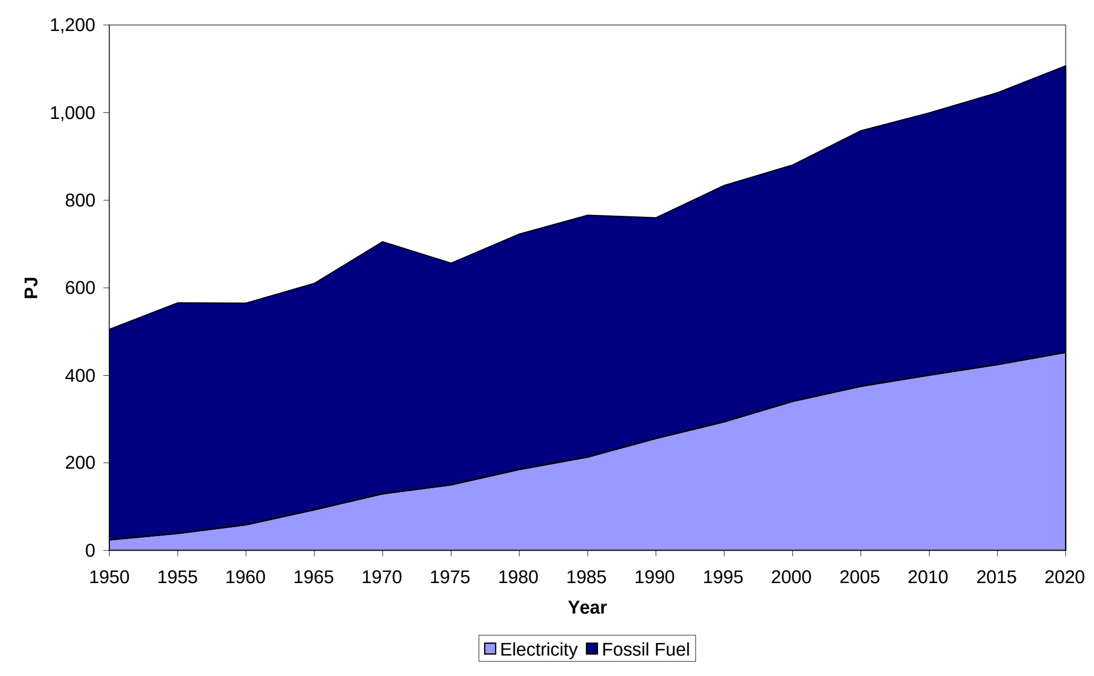
Figure 4.5: The contribution of each model input to the total carbon emissions projections



* This is a weighted average of electricity and fossil fuels.

Figure 4.6 gives an indication of the changing contributions of electricity and fossil fuels to total energy consumption between 1950 and 2000, with projections to 2020. It is clear that the proportion of electricity has increased significantly over the years; fossil fuel consumption, however, shows a much more gradual increase. In the projection period (2000 - 2020) fossil fuel consumption continues to increase, since the increase in floor area over this period outweighs the increases in boiler efficiencies and improvements to the building envelope. Furthermore, the increasing proportion of electricity is because increasing floor area and increasing demand for particular items which are not yet at saturation point (in particular computing equipment and cooling) outweigh the large increases in the efficiency of electrical equipment over this period.

Figure 4.6: Change in total energy consumption over time, showing the proportions of fossil fuel and electricity (2000 to 2020 represent the projected figures)



The following graphs (Figures 4.7 and 4.8) show the contribution of each sub-sector to the total energy consumption and carbon emissions. Tables D.1.1 and D.1.2 in Appendix D also give a summary of these results.

The education sub-sector shows an initial growth to 2010 and then stabilises as the proportion of children in the population levels off. Retail shows the greatest increase in energy consumption and this is partly a result of the projected increase in floor area, but also due to longer opening hours. Emissions from the retail sector are even more pronounced than for energy. This arises because retail uses a higher proportion of electricity compared to other sectors and the emission factor for electricity is much greater than that for fossil fuels. The commercial offices sub-sector also shows a noticeable increase in energy consumption and related carbon emissions, as does hotels and catering. These are largely due to the projected increases in floor area.

Figure 4.7: UK commercial and public sector energy consumption by sub-sector for the reference scenario

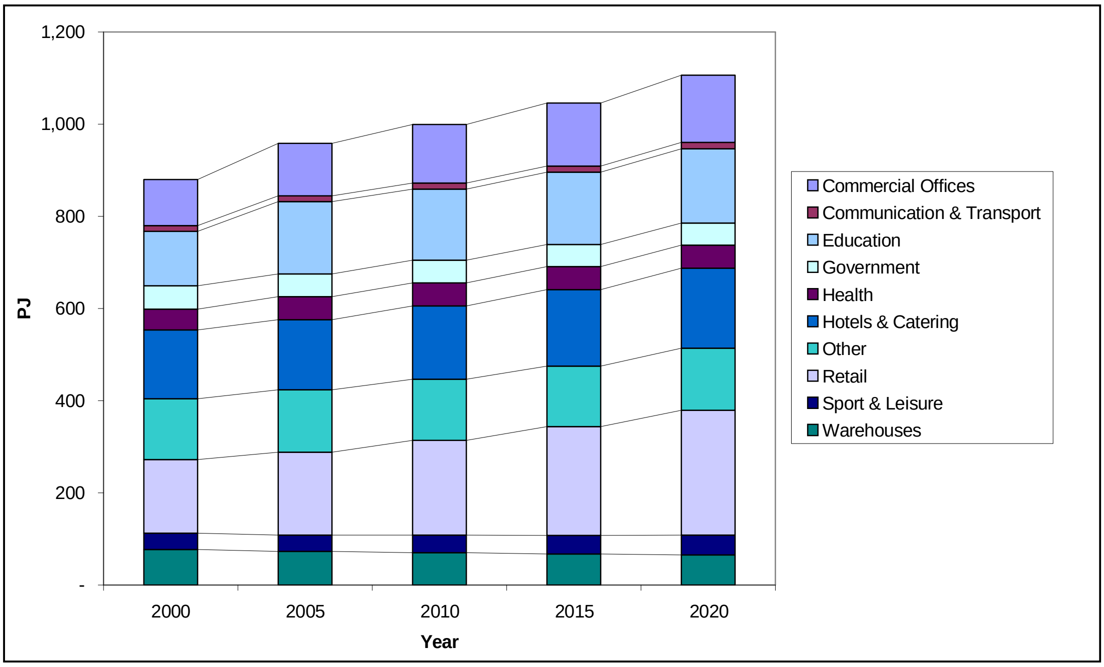
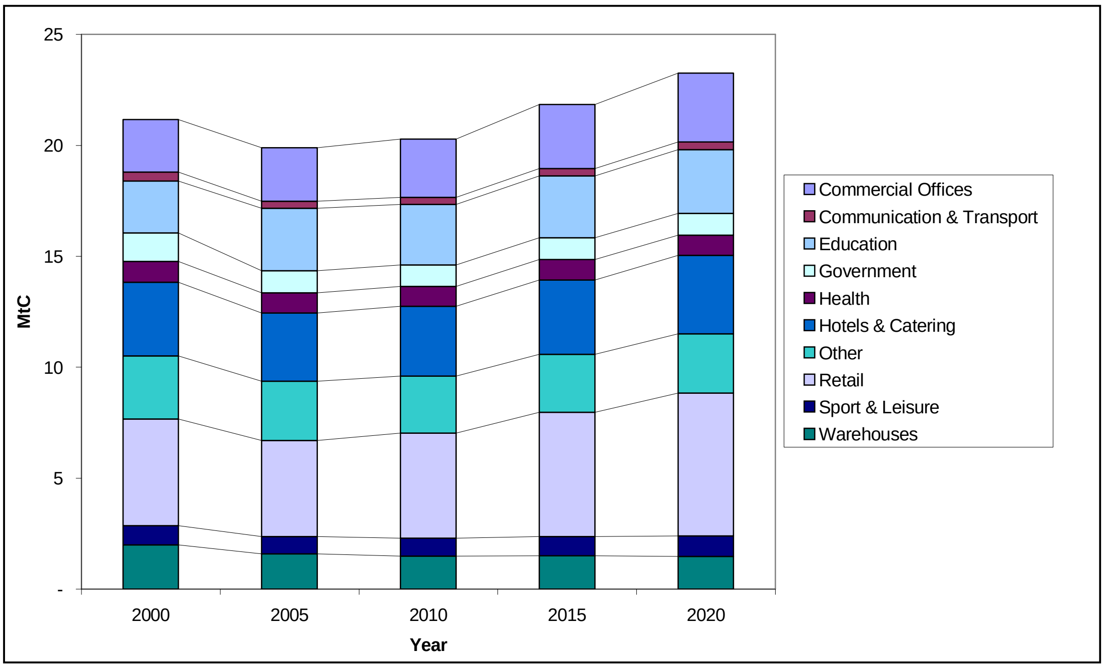


Figure 4.8: UK commercial and public sector carbon emissions by sub-sector for the reference scenario



Due to the bottom-up technological approach used to construct these projections, an indication of the likely changes within each end-use is produced from the model. These potential changes are demonstrated for the commercial and public sector reference scenario in Figures 4.9 and 4.10, which show energy consumption and related carbon emissions disaggregated by end use. Tables D.1.3 and D.1.4 also summarise these results. Whilst all end-uses show some increase in energy consumption, cooling energy use, despite only contributing a small proportion of total consumption, rises dramatically. This arises largely from the continuation of recently observed trends in the increasing installation of cooling, particularly in newer and larger buildings. The influence of the changes in electricity emission factors can be seen in the carbon emissions trends with electricity-consuming end-uses making up a greater proportion of the emissions than they do energy consumption. Heating and lighting both show a slight decrease in emissions, mainly due to the assumed uptake of energy efficiency measures for these end-uses. Furthermore, energy use for heating is curbed to some degree due to the obligation that all new buildings meet the higher standard of energy efficiency required by the revised Building Regulations[16].

Analysing some of the major sub-sectors and how the end-uses are projected to change within these can explain the changes depicted in the Figures 4.9 and 4.10 below. Commercial offices have a high proportion of cooling relative to the other sub-sectors. They also have a relatively high proportion of office equipment which, in itself, is a driver for installing cooling in this sub-sector. Energy consumption for all end-uses within this sub-sector is expected to grow to 2020. Cooling shows the greatest increase between 2000 and 2020, and is a predominant factor in rising carbon emissions in this sub-sector.

Energy consumption in the communication and transport sub-sector remains reasonably stable due to the combination of only a small increase in floor area combined with increases in technology efficiency (particularly lighting). Due to the stable energy consumption, carbon emissions actually show a decrease in this sub-sector mainly due to the lower electricity emission factors after 2000.

The demand for heating in the health sub-sector actually decreases very slightly over the time period, this is mainly as a result of the very slow increase in floor area being cancelled out by improvements to the heating systems and the building envelope.

In the hotel and catering sub-sector the increase in energy consumption and carbon emissions from cooling is notable. This is a reflection of the increase in consumer demand for cooling in this sub-sector, as well as the general acknowledgement in the air conditioning industry that hotels are becoming increasingly more likely to install air conditioning right down to the economy end of the market[17].

As discussed in Sections 4.2 and 4.3, the retail sub-sector shows a large increase in consumption and emissions due to the large increase in floor area combined with longer opening hours.

Figure 4.9: UK commercial and public sector energy consumption by end-use for the reference scenario

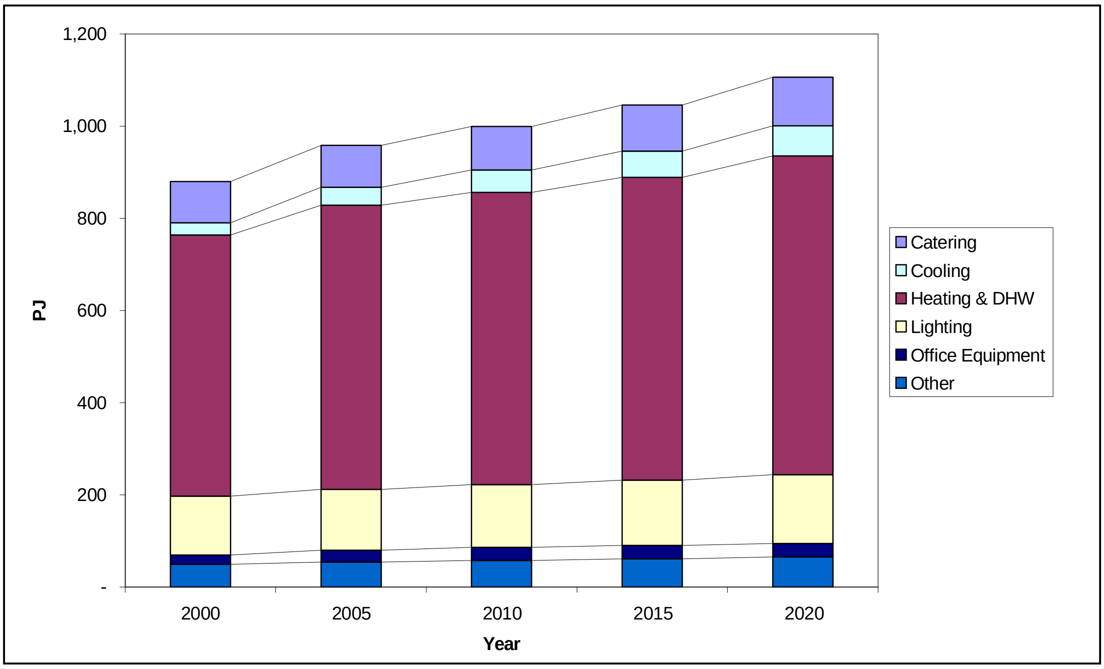
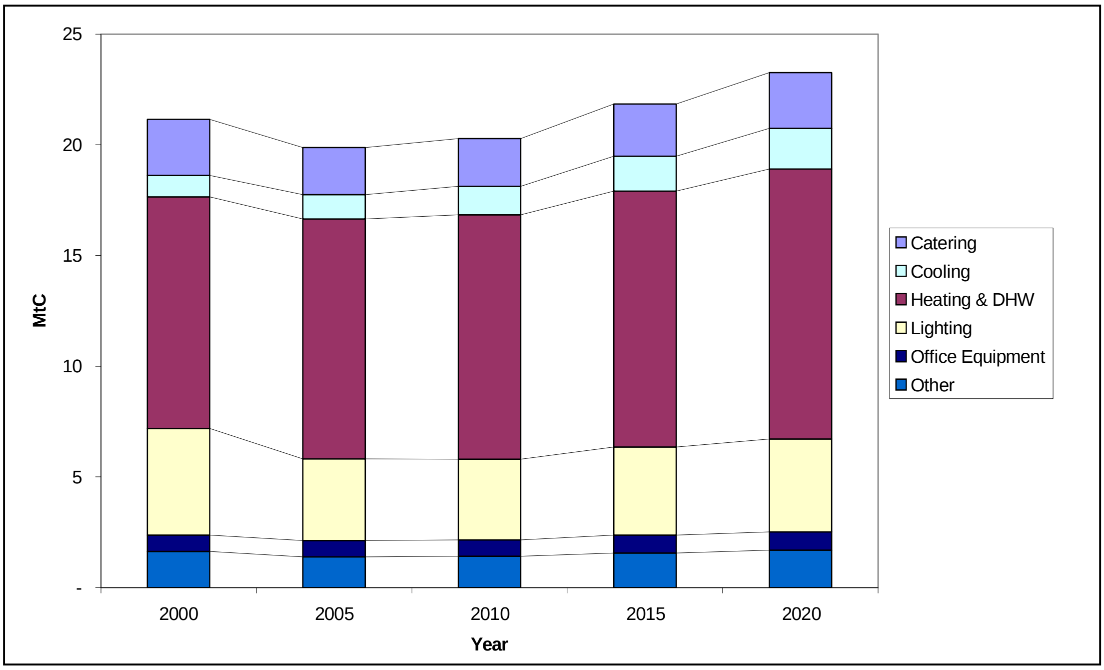


Figure 4.10: UK commercial and public sector carbon emissions by end-use for the reference scenario



4.6 Efficiency Scenario

The efficiency scenario represents an enhanced uptake of efficiency measures compared to the reference scenario. In order to achieve this it was assumed that the fastest feasible uptake rate would be observed for all efficiency measures. The model implicitly assumed that whenever an investment decision was made the most energy efficient option that is cost effective would be chosen. The analysis of cost effective options, described in Part Three, was used to determine the proportion of instances in which each measure was likely to be cost effective. For example, condensing boilers were shown to be cost effective in 87% of instances, thus it was assumed that 87% of all boiler purchases would be of the condensing type. This scenario assumes no market barriers and represents the maximum carbon savings that could be achieved cost-effectively. All other modelling assumptions are the same as for the reference case, so again only currently available technologies are considered.

Figure 4.11 compares energy consumption for the reference case to that of the enhanced efficiency scenario. The efficiency scenario shows 2020 energy consumption stabilising at 2000 levels, with an overall 1% decrease between 2000 and 2020. This compares to a 26% increase in energy consumption for the reference scenario (Table 4.2). The efficiency scenario indicates a rapid decrease in consumption to 2005 followed by a subsequent increase, albeit at a much slower rate than the reference scenario. The initial rapid decrease is a result of significant uptake of cost effective energy efficiency options that could be implemented quickly. As much of the cost effective potential is attributable to lighting equipment which has a short lifetime, this results in a rapid increase in the efficiency of these end-uses. However, once these changes have been made the potential is much reduced and replacement cycles are longer, hence the reduction in consumption compared to the reference case is much less pronounced beyond 2005.

Figure 4.11: Projections of energy consumption in the UK commercial and public sector for the reference and efficiency scenarios

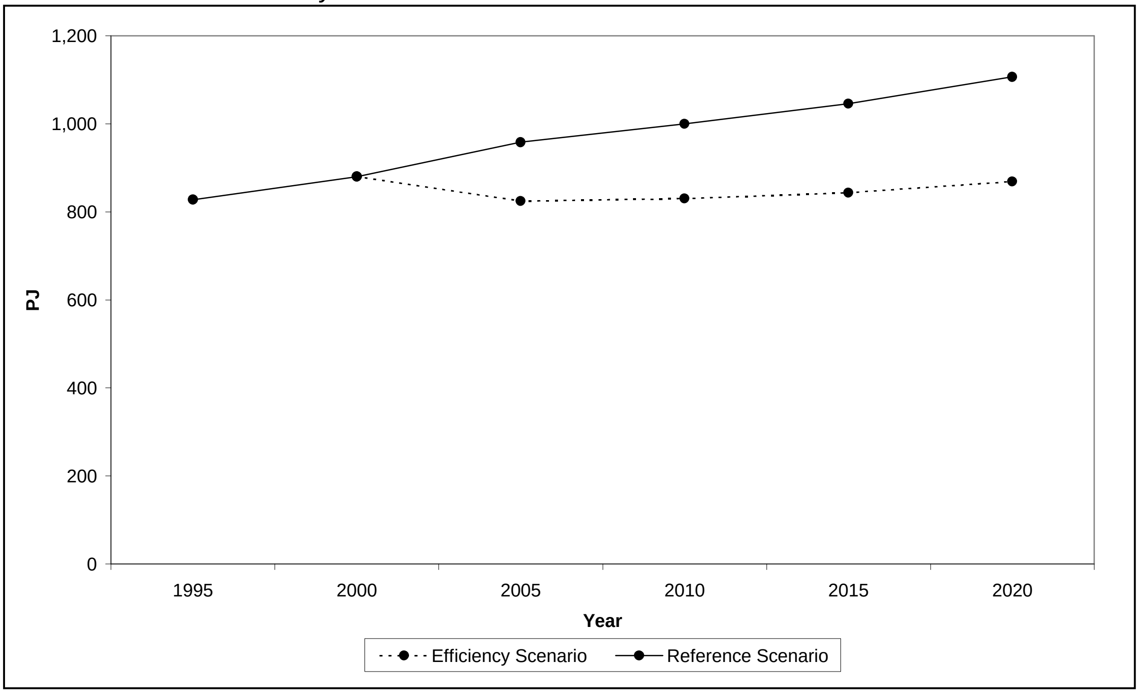
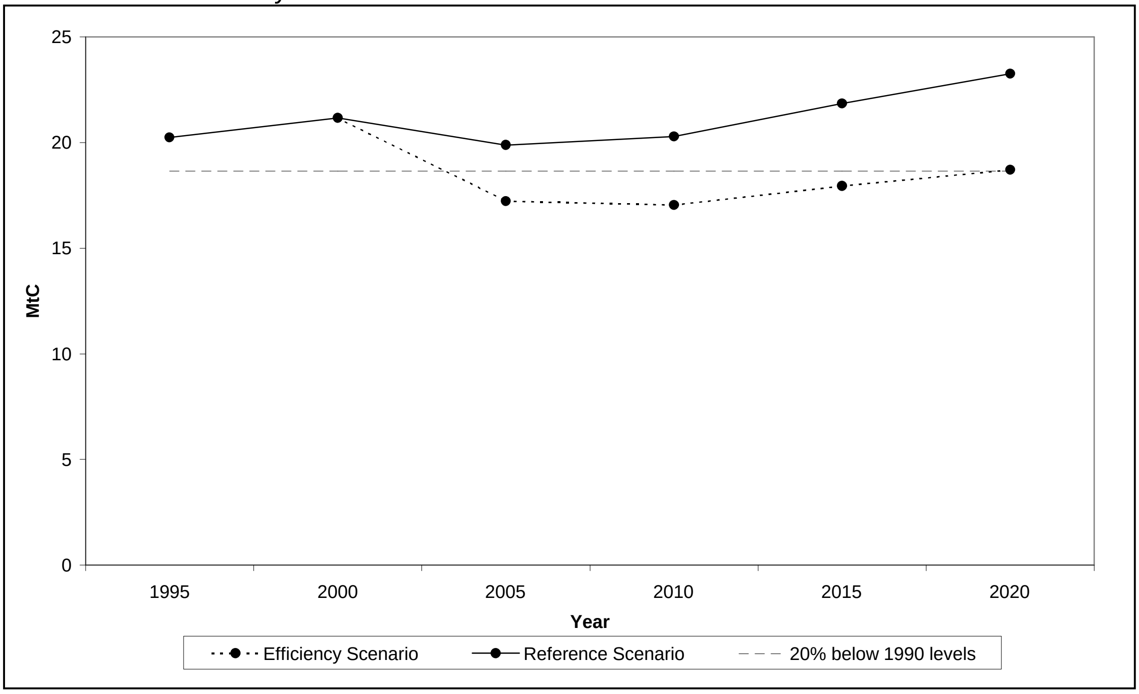


Figure 4.12: Projections of carbon emissions in the UK commercial and public sector for the reference and efficiency scenarios



The carbon emissions projections depicted in Figure 4.12 show that under the efficiency scenario, emissions decrease to 2005, remain relatively stable to 2010 and subsequently increase to 2020. This subsequent increase is partly a result of the increase in the electricity emission factor but also reflects the reduced scope for implementing cost effective efficiency measures after 2010. Additionally, floor area increases after 2010 begin to exceed take up of energy efficiency options since this scope is becoming saturated.

Moreover, this indicates that a 20% reduction in carbon emissions by 2010[x] could be achieved in public and commercial buildings by implementing energy efficient options that are currently available. Furthermore, these savings are achieved despite significant growth in this sector.

Table 4.2: Changes in floor area, energy demand and carbon emissions for the reference and efficiency scenarios

Year	Floor Area (% change from 2000)	Energy Consumption (% change from 2000)		Carbon Emissions (% change from 2000)	
		Reference Scenario	Efficiency Scenario	Reference Scenario	Efficiency Scenario
2000	0%	0%	0%	0%	0%
2005	5%	9%	-6%	-6%	-19%
2010	9%	14%	-6%	-4%	-19%
2015	12%	19%	-4%	3%	-15%
2020	17%	26%	-1%	10%	-12%

[x] Compared to 1990 levels.

The distributions of energy consumption and carbon emissions by sub-sector under the efficiency scenario are shown in Figures 4.13 and 4.14. These results are also summarised in Appendix D in Tables D.2.1 and D.2.2. It is clear that each sub-sector contributes to the savings accrued. Education shows one of the greatest reductions in energy consumption between the reference and efficiency scenarios in 2020. This is predominantly as a result of a fast uptake of efficient boilers in a sub-sector currently dominated by old, inefficient boilers.

The retail sub-sector dominates both consumption and emissions and, despite only limited increases to 2010 under this scenario, the increases subsequently become more apparent.

Figure 4.13: UK commercial and public sector energy consumption by sub-sector for the efficiency scenario

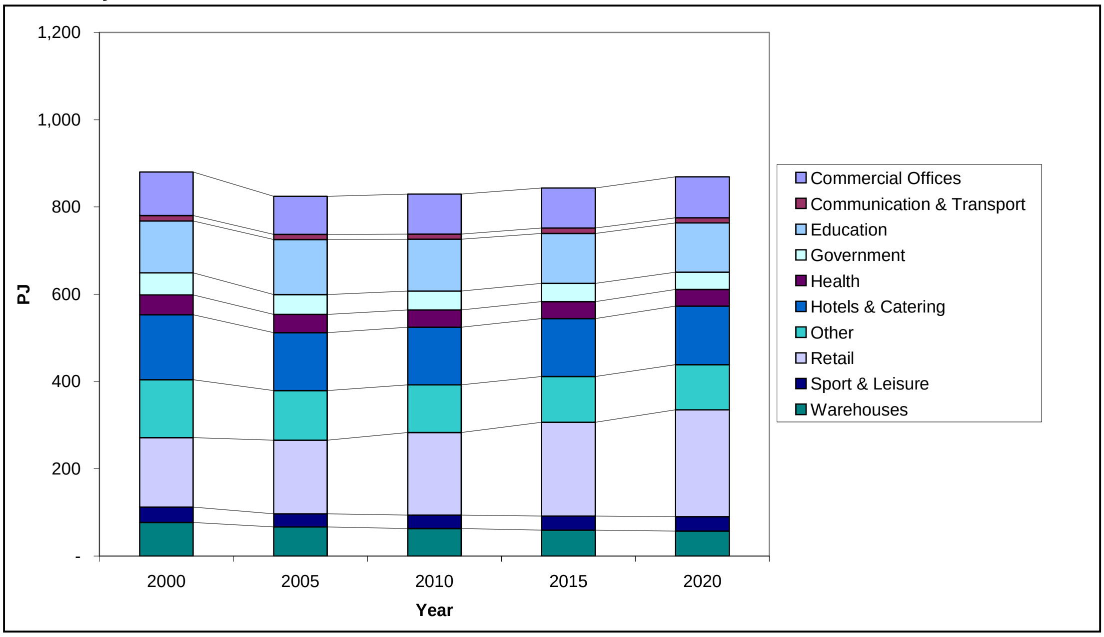
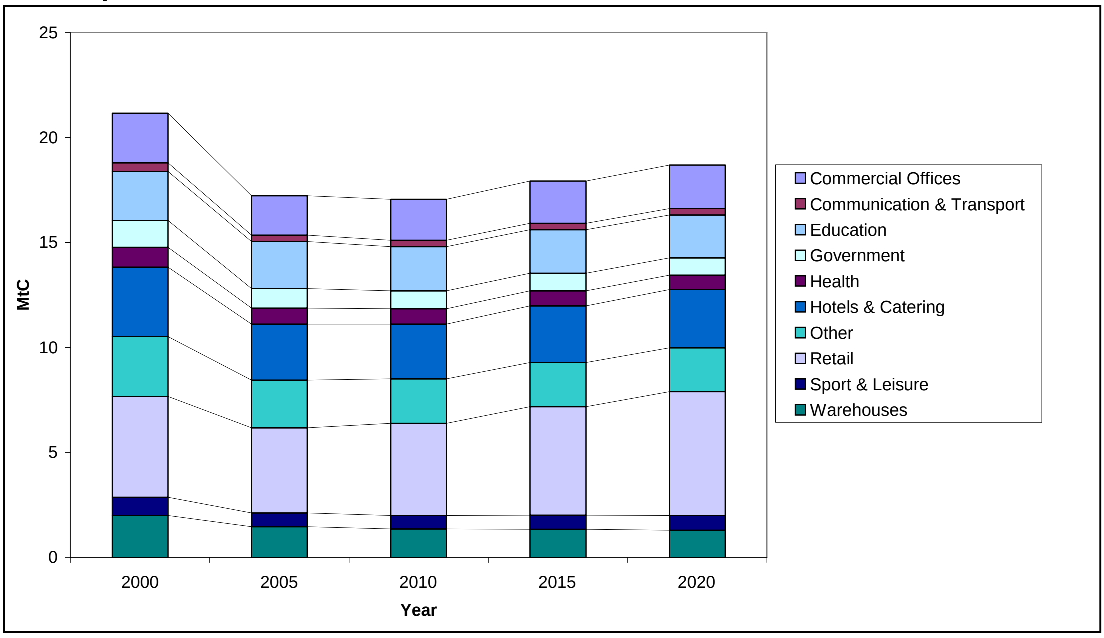


Figure 4.14: UK commercial and public sector carbon emissions by sub-sector for the efficiency scenario



The trends in energy consumption and carbon emissions by end-use under the enhanced efficiency scenario are shown in Figures 4.15 and 4.16. The numbers behind these figures are given in Tables D.2.3 and D.2.4. The initial drop to 2005 is predominantly due to heating and lighting measures. The effects of the short lifetime and fast uptake rate of efficient lighting measures are clear in both graphs. The heating trend indicates the increased uptake of efficient boilers under the efficiency scenario. Although boilers do not have a particularly short lifetime, typically 10 to 15 years, many of the boilers in the commercial and public sector building stock are older than this and thus replacement of these occurred relatively quickly under the efficiency scenario.

Even under the efficiency scenario, cooling is continually increasing in both consumption and emissions to 2020. This is because the rapid increase in cooled space outstrips the impact of more efficient cooling technologies under the efficiency scenario.

Once again, the carbon emissions trends reflect the change in the electricity emission factor.

Figure 4.15: UK commercial and public sector energy consumption by end-use for the efficiency scenario

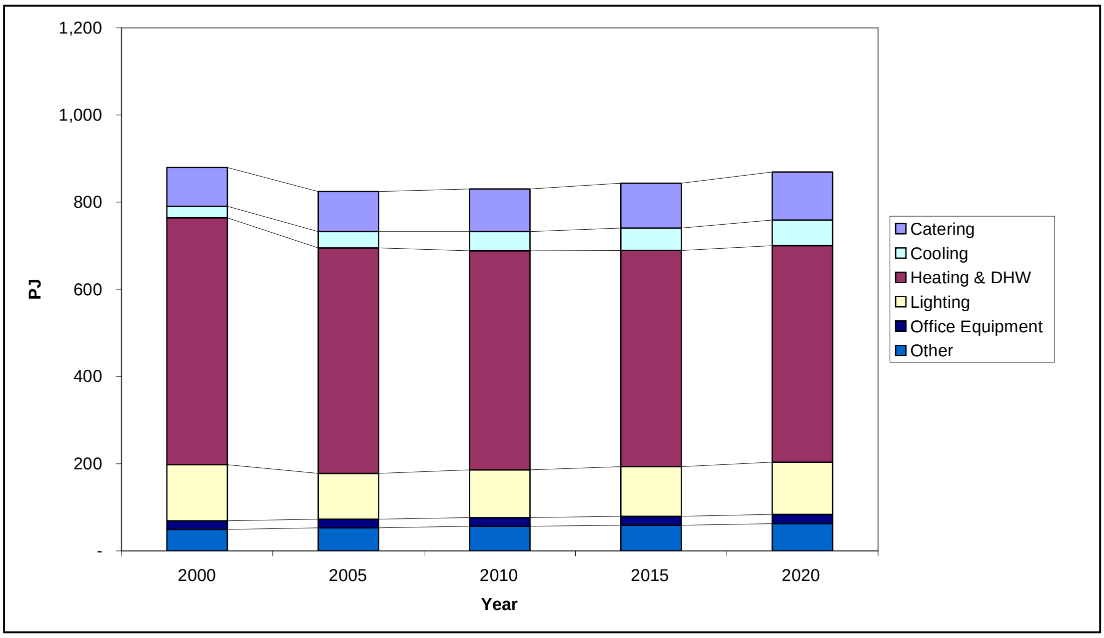
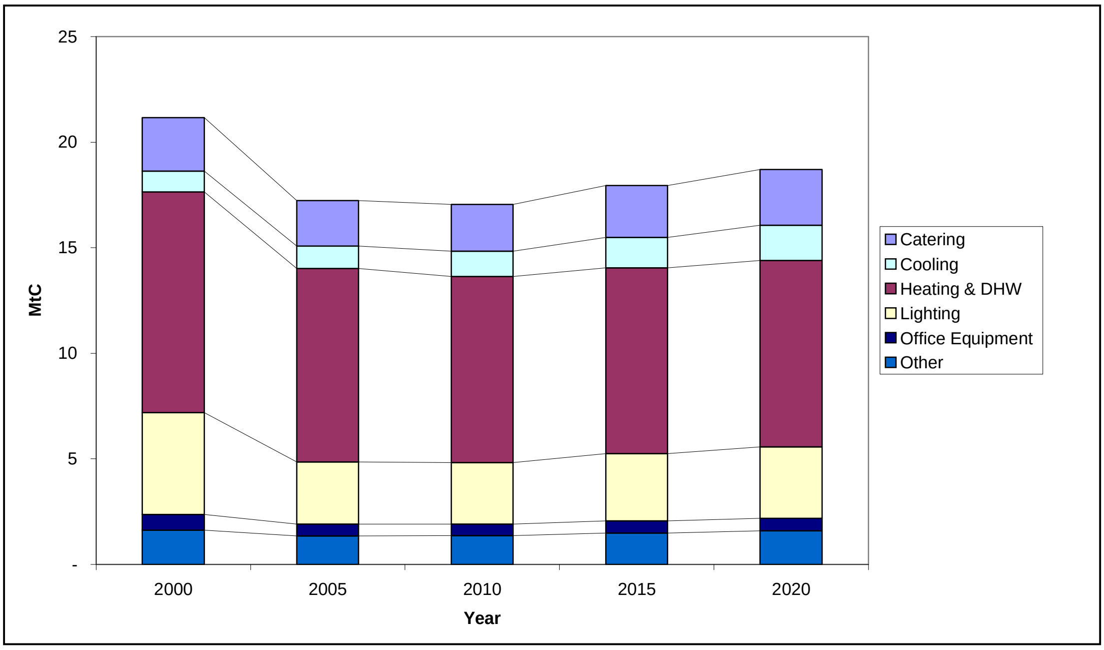


Figure 4.16: UK commercial and public sector carbon emissions by end-use for the efficiency scenario

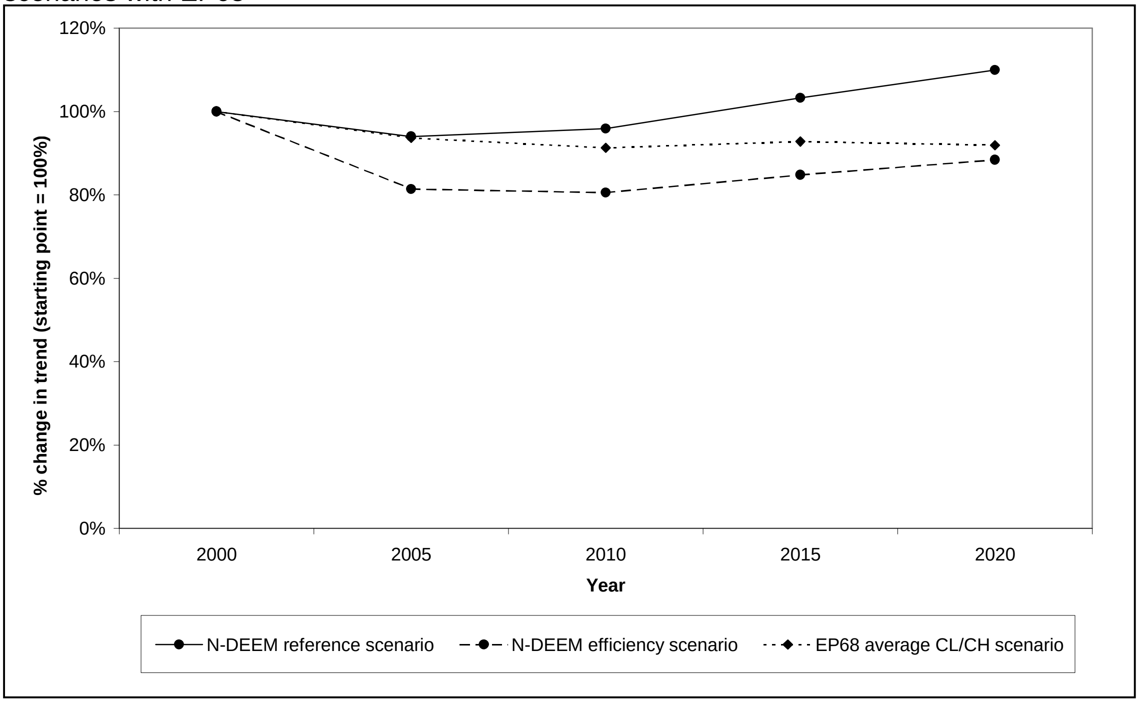


4.7 Comparison to DTI Energy Paper 68

Figure 4.17 compares the carbon emission trend lines from the reference and efficiency scenarios with the average of the CL/CH[y] trend line from DTI's Energy Paper 68 (EP68)[12]. The 2000 carbon emission figures in EP68 were necessarily based on estimated 2000 energy consumption[z], which is 8% higher than the reported consumption that the N-DEEM results are based on. To allow for comparison, therefore, the trends have been plotted as a percent change from 2000.

Figure 4.17 shows that the EP68 trend line lies within the boundaries of the N-DEEM reference and efficiency scenarios. In fact the reference and EP68 scenarios are very similar to 2005. After 2010 the EP68 trend line remains relatively flat, diverging from the reference trend, but converging with the efficiency trend. This is probably due to the implicit assumption within the DTI's top-down projections that overall efficiency will continue to improve as it has done in the past; whereas the bottom-up analysis carried out here explicitly models the uptake of existing energy efficiency options. Furthermore, there may also be differences between the sector growth assumptions in EP68 and those in the N-DEEM scenarios.

Figure 4.17: Comparison of the trend lines produced from the reference and efficiency scenarios with EP68



[y] CL refers to the central growth, low cost scenario; CH refers to the central growth, high cost scenario. An average of these scenarios was used for this comparison.

[z] EP68 was published in 2000, therefore actual figures for 2000 were not known at the time of publication.

4.8 Policy Scenario: Effect of Government policies set out in the Climate Change Programme

A number of policies incorporated in the Climate Change Programme[3] are aimed at the commercial and public sector. The Programme gives some indication of the likely savings from each policy in terms of a total for all UK sectors. Here, the policies have been broken down to show the effect they could have on commercial and public sector emissions. All relevant policies have been considered from a bottom-up perspective as far as was possible, as discussed below.

The Integrated Pollution Prevention and Control (IPPC) Directive[aa] and the negotiated agreements with sector bodies as part of the climate change levy package applies only to industrial sector premises and thus has not been considered further in this analysis.

The effect of enhanced capital allowances (ECAs) on the cost-effectiveness of eligible energy efficiency equipment (listed on the ECA products list[bb]) was modelled. The increased tax allowances that ECAs attract effectively equates to a 13% reduction in capital costs for those paying tax at the standard rate and were modelled as such. This indicates that, with the introduction of ECAs, an additional 0.25 MtC per year could be saved cost effectively by 2010.

The impact of the first stage of a UK Emissions Trading Scheme was assessed based on the study of potential participants carried out for the Government[18]. Emissions trading effectively puts a monetary value on carbon savings. The UK Emissions Trading Scheme is expected to be achieved primarily through the incentive created to take up cost effective opportunities that are already existing, rather than creating new cost effective opportunities[cc]. Assuming that only companies with over 500 employees would enter the first phase of the Scheme, and that those that did enter would achieve 50% of their cost effective carbon savings it was estimated that an additional 0.22 MtC could potentially be saved in 2010.

The Regulatory Impact Assessment of revisions to Part L of the Building Regulations[19] gives carbon savings in the commercial and public sector of around 0.39 MtC[dd]. These revisions are expected to come into force in 2002.

For public sector and Scottish targets the figures given in the Climate Change Programme were used directly.

[aa] IPPC is aimed at preventing or reducing pollution from industrial activities across England and Wales. The IPPC Directive takes a wide view of pollution and includes emissions to land, water and air, as well as waste, noise and heat pollution. Permits are issued and emissions are independently monitored and checked in relation to these permits, and that the general principles embodied in the Directive pertaining to preventing or minimising pollution are being adhered to.

[bb] It should be noted that the product list may change in the future so that measures that are currently on the list may be removed (as they become standard rather than efficient products) and up and coming efficiency products may be added in the future.

[cc] The effect of a cost of £30 per tonne of carbon saved on the cost-effective potential for reducing carbon emissions in non-domestic buildings was modelled. This resulted in a 1% increase in the cost effective potential for carbon savings.

[dd] This was calculated using the same data and bottom-up modelling techniques described in this report.

Table 4.3 below shows the savings attributed to each policy as a result of the analyses undertaken. In order to produce a trend line, it was assumed that no additional policies were implemented after 2010, thus the annual savings would not change beyond that year. The 2005 savings, however, were determined by assuming the same proportion of the efficiency scenario had been achieved in 2005 as in 2010. Once the annual savings were determined, the trend was calculated as a perturbation of the reference scenario. As a consequence of the fast uptake rates in the efficiency scenario in the first five years (as discussed in Section 4.6), the policy savings for 2005 are likely to be optimistic. The savings for 2010, however, have been calculated as described earlier and so give a more robust indication of savings.

Table 4.3: Results of analysis to determine cumulative savings attributed to each policy compared to the reference case

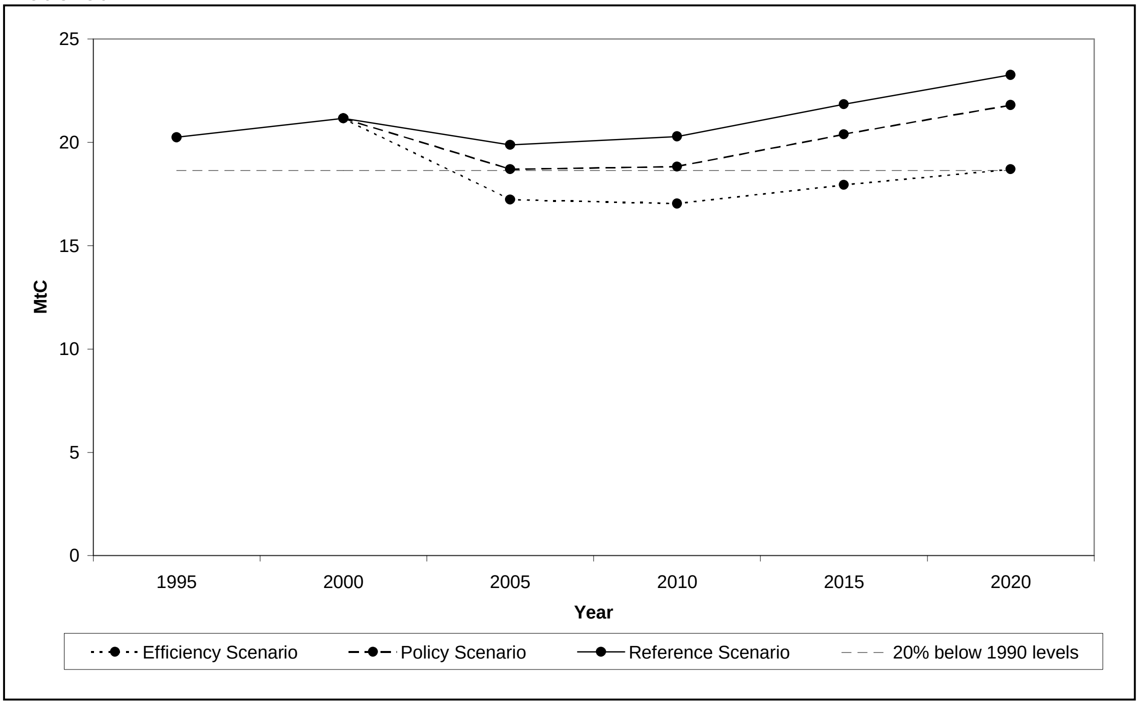
Policy Measure	**2005 savings (MtC)**	**2010 savings (MtC)**	**2015 savings (MtC)**	**2020 savings (MtC)**
Climate Change Agreements & IPPC	0	0	0	0
ECA's	0.20	0.25	0.25	0.25
1st Stage of Emissions Trading Scheme	0.18	0.22	0.22	0.22
Reform of Building Regulations	0.32	0.39	0.39	0.39
Public Sector Targets	0.41	0.50	0.50	0.50
Scottish Regulations & Targets	0.08	0.10	0.10	0.10
Total	**1.19**	**1.46**	**1.46**	**1.46**

Figure 4.18 is a graphical representation of the policy scenario trend line in relation to the reference and efficiency scenarios. Until 2010 the policy scenario lies around half way between the reference and efficiency scenarios. Between 2010 and 2020, however, the policy line becomes progressively closer to the reference line. This is because the model assumes no additional carbon savings from policy actions beyond 2010[ee]. This also demonstrates the potential need for further policies to be introduced after 2010 in order to stabilise or reduce emissions.

The policy scenario emissions are estimated to be around 18.8 MtC in 2010, a decrease of 7% relative to the reference scenario. The policy scenario indicates a saving of 19% on 1990 emissions in 2010[ff].

[ee] Other than the savings that will already be made from policy actions, which are assumed to persist in future years.
[ff] 1990 emissions were 23.3 MtC.

Figure 4.18: Commercial and public sector carbon emissions projections for all scenarios modelled



Bottom-up estimates of how the carbon savings might be distributed across the sub-sectors were made, as shown in Figure 4.19 and also in Table D.3.1 (Appendix D). In many instances the impact of the policy scenario is to reduce emissions in 2005, which stay relatively constant to 2010 and subsequently increase to 2020. (As mentioned previously (Section 4.6), because the estimates of 2005 savings are based on the pattern of change demonstrated in the efficiency scenario, the fast uptake rates in the first five years mean that the policy savings for 2005 are likely to be optimistic).

The Emissions Trading Scheme only influences retail and commercial offices to a notable extent and, in this scenario, contributes the greatest amount to the total carbon savings from policies for both of these sub-sectors. Retail, however, shows a marked increase after 2010 as floor area growth increases substantially, yet the annual policy savings relative to the reference scenario remain unchanged beyond 2010 as the model assumes that there are no additional policies after this date.

The importance of achieving the public sector targets is evident between 2000 and 2005 for the government and health sub-sectors. For education, however, potential savings would be outstripped by floor area growth in this period.

Figure 4.19: UK commercial and public sector carbon emissions by sub-sector for the policy scenario

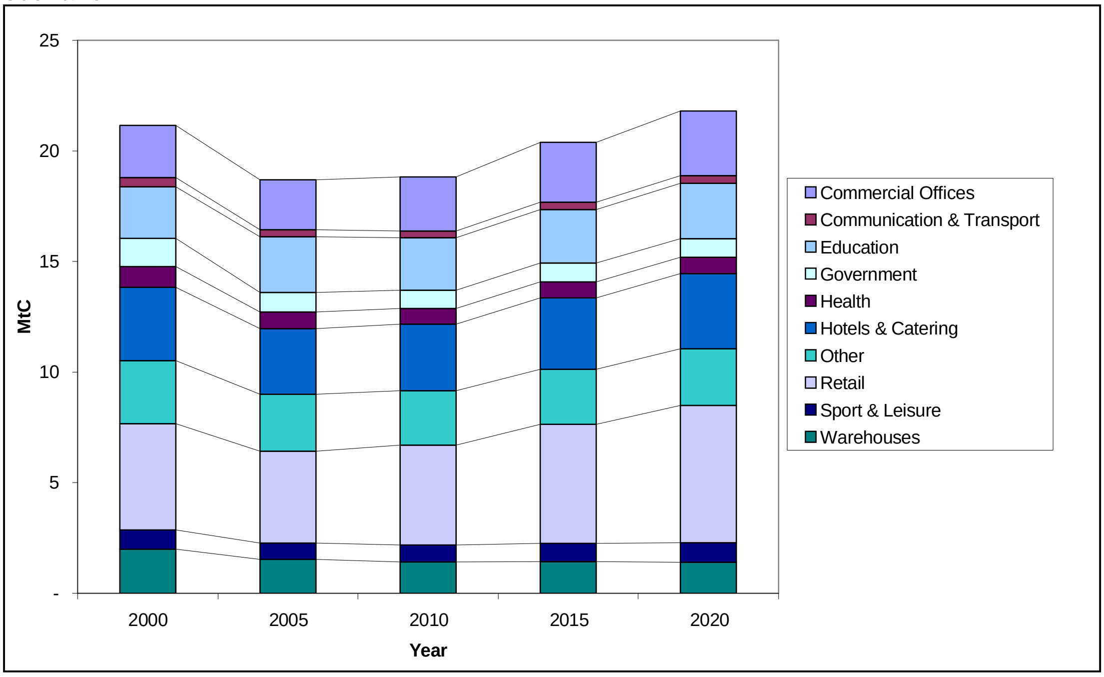
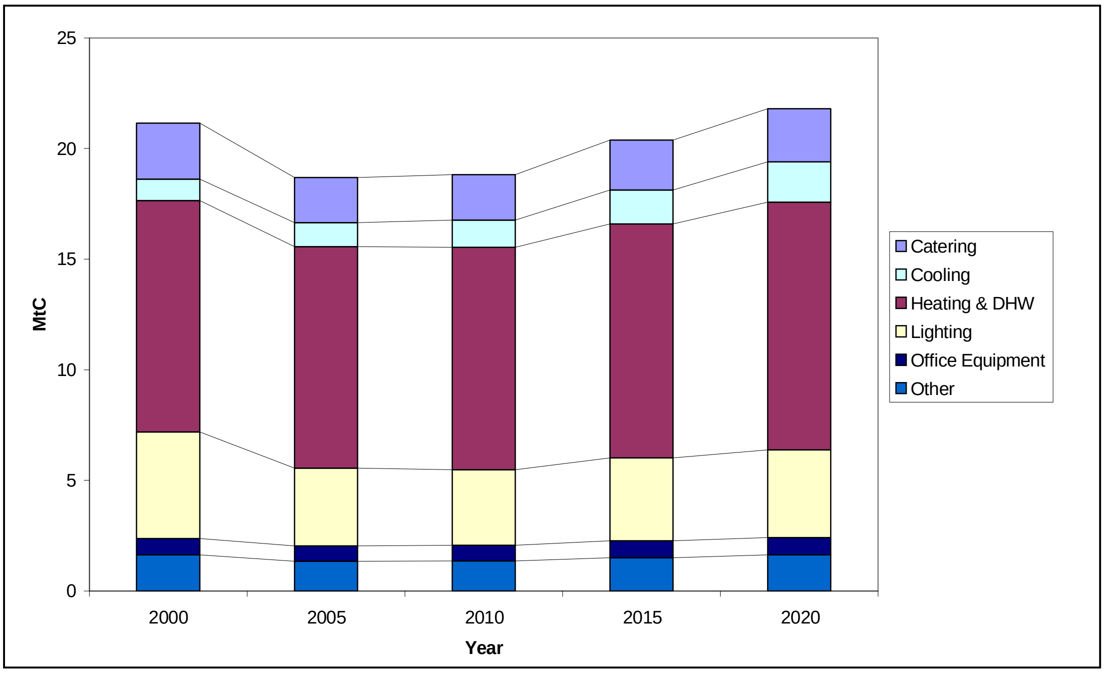


Figure 4.20 shows estimates of the breakdown of savings by end-use, these figures are also summarised in Appendix D, Table D.3.2. (It should be noted that the 2005 savings are likely to be an overestimate).

The majority of savings are made in heating and lighting. For heating this is due to the effects of the revised building regulations on heating systems and the building envelope, as well as the effects of ECAs on boilers. The significant savings in carbon emissions from lighting, which could be realised under the policy scenario, are mainly as a result of ECAs for lighting and lighting controls.

Emissions from each end-use rise after 2010, since no additional savings beyond 2010 are assumed in the model, only that the savings from the policies considered will persist.

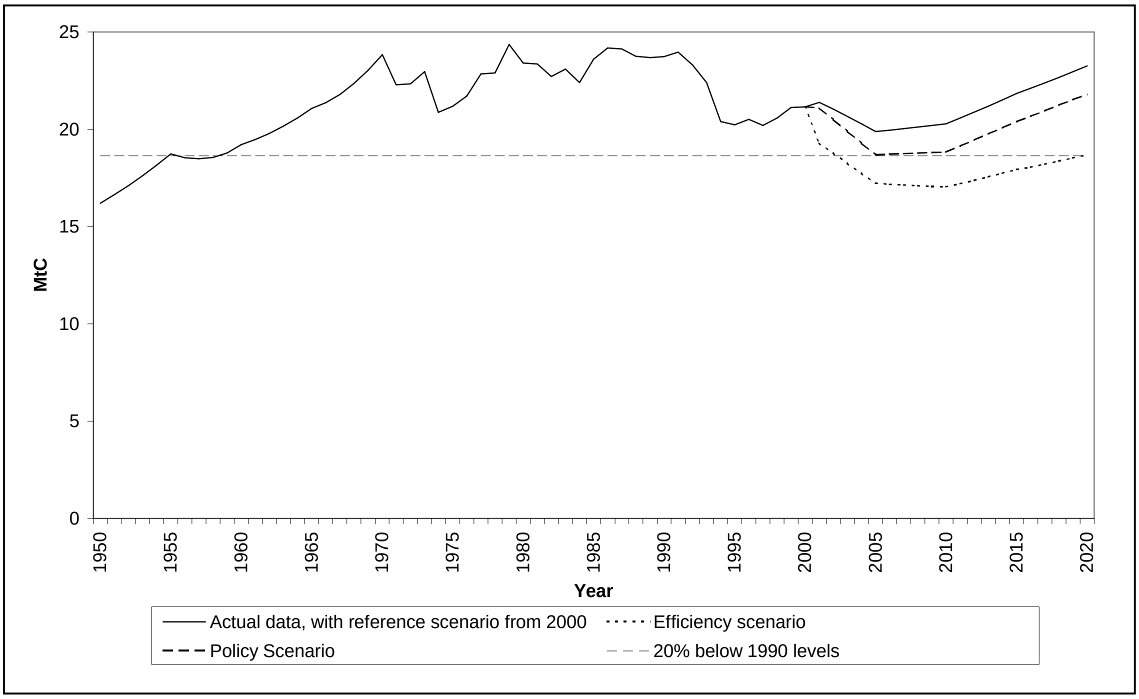
Figure 4.20: UK commercial and public sector carbon emissions by end-use for the policy scenario



4.9 Carbon Emission Trends in a Wider Context

A picture of the longer-term trends in UK commercial and public sector carbon emissions is provided in Figure 4.21, along with the three scenarios discussed in Sections 4.5, 4.6 and 4.8 above. The increase in emissions between 1950 and 1970 was due to economic expansion during a period when electrical goods became much more widely available, which had a marked impact on overall emissions, as emissions from electricity were much higher than they are now. The impact of the oil crisis is reflected by the decrease in emissions in the 1970s which accelerated the switch to natural gas. The further increase in emissions in the 1980s coincided with a buoyant UK economy. This was followed by a sudden reduction in emissions in the early 1990s, which was in part a consequence of lower levels of economic activity experienced in the UK at that time. More recently, the drop in emissions which continued through the 1990s was linked to the increase in the amount of electricity originating from combined cycle gas turbine (CCGT) generators which resulted in a lowering of the average electricity emission factor. The decrease was probably also linked to a better understanding of the need to decrease emissions, and some action resulting from this. The increase in the late 1990s was mainly due to a decline in electricity generated by nuclear power stations, with some consequent increase in the use of fossil fuels including coal[14], thus causing a rise in the average emission factor for electricity.

Figure 4.21: Longer term carbon emissions trends in the UK commercial and public sector, including N-DEEM reference, efficiency and policy scenarios



Observing the three future scenarios, it is clear that the reference scenario shows a small decrease in emissions, followed by a rapid rise after 2010, almost on the same scale to that seen between 1950 and 1970. Under the enhanced efficiency scenario emissions could almost drop to 1950 levels by 2010. Under the policy scenario emissions drop to 1960 levels by 2010, however they subsequently increase at a rapid rate, also similar to the rise seen between 1950 and 1970. There is certainly scope for non-domestic buildings to make a proportionate contribution to meeting the UK's current international commitments and domestic goals on emissions mitigation. However, continued technological development, innovation and increased awareness will be needed to modify the tendency of emissions to increase in the longer term.

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Appendices

Appendix A: Emission Factors

A.1 Carbon Emission Factors for Delivered Energy

Burning fossil fuels inherently results in the release of carbon dioxide (CO_2). Different fuels contain different carbon contents and calorific values, therefore the CO_2 released from burning a unit of fuel varies depending on the fuel type. Here, emissions from delivered energy have been considered since this takes account of the wider environmental impacts of burning fossil fuel, by considering fuel extraction and processing, as well as point-of-use emissions.

Table A.1 shows that gas produces the least carbon emissions per unit of energy burned, and electricity produces the highest. The different emission factors for each of the economic sectors listed is a result of the mix of coke, coal and solid fuel grades used, the mix of petroleum products used in oil, and the mix of public supply and own generation for electricity.

Table A.1: Carbon emission factors for delivered energy by fuel type for 2000

Average kgC/GJ	Coal	Coke	Coke Oven Gas	Other Solid	Oil Products	Natural Gas	Electricity	Average
Industry	**22.1**	**28.2**	**16.7**	**26.7**	**20.2**	**14.6**	**37.1**	**20.8**
Iron & Steel	22.1	28.2	16.7	-	20.5	14.6	37.2	16.4
Other Industry	22.1	28.2	16.7	26.7	20.2	14.6	37.1	21.5
Transport	**-**	**-**	**-**	**-**	**19.9**	**-**	**37.6**	**20.1**
Air	-	-	-	-	20.0	-	-	20.0
Rail	-	-	-	-	20.2	-	37.6	29.0
Road	-	-	-	-	19.9	-	-	19.9
National Navigation	-	-	-	-	20.3	-	-	20.3
Other	**22.8**	**28.5**	**-**	**26.7**	**20.2**	**14.6**	**37.5**	**20.5**
Domestic	22.8	28.5	-	26.7	20.0	14.6	37.6	19.4
Public Administration	22.8	-	-	-	20.4	14.6	37.4	20.6
Commercial	-	-	-	-	20.3	14.6	37.6	26.8
Agriculture	22.8	-	-	-	20.3	14.6	37.6	22.4
Miscellaneous	22.8	-	-	-	20.2	14.6	-	14.9
Average All Sectors	**22.5**	**28.2**	**16.7**	**26.7**	**20.0**	**14.6**	**37.4**	**20.4**

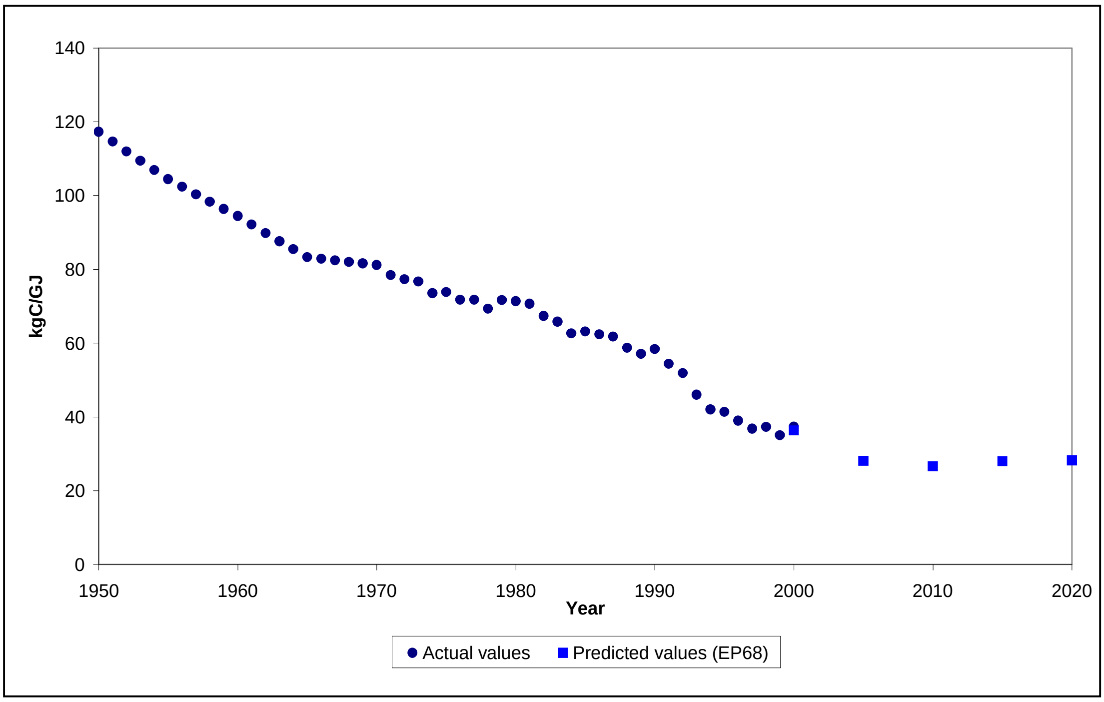
A.2 Changing and Future Emission Factors from Electricity

Emission factors for electricity reflect the fuel mix used to generate electricity. The average fuel mix for a given year is used to calculate annual emission factors for electricity. Future projections of electricity emission factors have been determined from the CL[gg] scenario in Energy Paper 68[12]. Figure A.2 shows that carbon emissions from electricity have been steadily falling since 1950. The slight rise in emission factors in 2000 was a result of a number of nuclear and gas powered stations being unavailable, and coal generation being used as a substitute[14]. Carbon emissions from nuclear stations are zero, and those from coal much higher than for gas, resulting in the increased emission factor.

[gg] Central growth, low cost scenario.

The projections indicate that emission factors will continue falling to 2010, followed by a subsequent increase to 2020. The projections estimate a decrease of 29% between 2000 and 2010 and 25% between 2000 and 2020. This continued fall to 2010 is partly as a result of the assumptions made in Energy Paper 68 that the Governments 10% renewables target will be met, that there will be an increase in CHP capacity, and the fact that the Climate Change Levy (CCL) is factored in.

Figure A.2: Change in carbon emissions from UK electricity generation 1950 - 2020



Appendix B: Activities Covered by Each Activity Group

Description of the activities covered by each activity group.

Activity Group	**Activity**
Commercial Offices	Commercial offices Insurance Other business services
Communication and Transport	Airport terminal Bus station Car park Petrol filling Railway undertaking Road haulage Telephone exchanges
Education	Other teaching Private colleges Private schools Public funded colleges Public funded schools Universities and former polytechnics
Government	Law court Local government offices National government offices and defence Other emergency Police station
Health	Inpatient Outpatient
Hotel and Catering	Boarding house Café Hostels Hotel Motel Pub Restaurant Takeaway food shop Wine bar
Other	Churches Club house Common areas Community centre Hall Holiday centre Holiday flats Homes Other rateable Printing and publishing/photographic processing Vehicle repair workshop Workshops

Retail	Bakeries Bank Betting shop Building society CTN Department and general Estate agent Food retailers Hairdressing salons Hirers electrical Laundries and launderettes Other personal services Other retail Post office Repairs (not vehicles) Vehicle showrooms
Sport and Leisure	Amusement arcade Bingo Cinema Leisure centre Libraries Museums Night-club Other leisure Other sporting Sports centre Stadia Swimming pool Theatre
Warehouses	Storage depot Stores Warehouse Whole sale distributor

Appendix C: Description of End-use Categories

Description of the types of energy consuming equipment and activities covered in each end-use group.

Grouped End Use	End Use	Description
Catering	catering	Ovens, hobs, food refrigeration, kettles, drink vending machines, and all kitchen appliances,
Computers	computer accessories	Printers, plotters, computer terminals, scanners and modems.
Computers	computer	Personal computers including screens. Servers and mainframe computers.
Computers	telecoms	Fax machines, switchboard, answer phone, telex machine.
Cooling and Ventilation	cooling	Split system, mobile air conditioning units, associated pumps and compressors and central plant equipment.
Cooling and Ventilation	fans	Desk fans, extractor fans and hoods, air handling units.
Cooling and Ventilation	HVAC controls	
Hot Water	DHW	Local water heaters, electric showers, calorifiers, immersion heaters, kettles used as a hot water source.
Heating	heating	All fossil fuelled space heating, storage heaters and other electrical heating, air circulation associated with heating, plus associated pumps.
Light	light	General illumination, task illumination, desk illumination, external lighting including signs.
Other	lifts	Goods and people
Other	other	Equipment with specialised uses, e.g., laboratory equipment, audio visual and photographic equipment
Other	pumps	Hot water circulation and serving drinks
Other	small power	Includes hand dryers, televisions, washing machines, vacuum cleaners and alarm systems.
Process	process	Equipment with specialised production uses, e.g., printing equipment, forklift trucks etc

Appendix D

D.1 Reference Scenario

Table D.1.1: UK commercial and public sector energy consumption by sub-sector

Sub-sector PJ	2000	2005	2010	2015	2020
Commercial Offices	99	113	128	136	146
Communication and Transport	13	13	13	13	14
Education	118	157	155	157	161
Government	51	50	49	48	48
Health	45	50	50	50	50
Hotel and Catering	149	152	159	166	174
Other	132	135	133	132	135
Retail	160	180	206	236	271
Sport and Leisure	35	36	38	40	43
Warehouses	77	73	70	67	65
Total	**880**	**958**	**1,000**	**1,046**	**1,107**

Table D.1.2: UK commercial and public sector carbon emissions by sub-sector

Sub-sector MtC	2000	2005	2010	2015	2020
Commercial Offices	2.4	2.4	2.6	2.9	3.1
Communication and Transport	0.4	0.3	0.3	0.3	0.4
Education	2.3	2.8	2.7	2.8	2.9
Government	1.3	1.0	1.0	1.0	1.0
Health	0.9	0.9	0.9	0.9	0.9
Hotel and Catering	3.3	3.1	3.1	3.4	3.5
Other	2.9	2.7	2.6	2.6	2.7
Retail	4.8	4.3	4.7	5.6	6.4
Sport and Leisure	0.9	0.8	0.8	0.9	0.9
Warehouses	2.0	1.6	1.5	1.5	1.5
Total	**21.2**	**19.9**	**20.3**	**21.8**	**23.3**

Table D.1.3: UK commercial and public sector energy consumption by end-use

End-use PJ	2000	2005	2010	2015	2020
Catering	89	91	95	100	106
Cooling	26	39	48	56	65
Heating and DHW	567	617	634	657	692
Lighting	128	131	137	142	149
Office Equipment	20	26	28	29	29
Other	49	54	57	61	65
Total	**880**	**958**	**1,000**	**1,046**	**1,107**

Table D.1.4: UK commercial and public sector carbon emissions by end-use

End-use MtC	2000	2005	2010	2015	2020
Catering	2.5	2.1	2.2	2.4	2.5
Cooling	1.0	1.1	1.3	1.6	1.8
Heating and DHW	10.5	10.8	11.0	11.6	12.2
Lighting	4.8	3.7	3.6	4.0	4.2
Office Equipment	0.8	0.7	0.8	0.8	0.8
Other	1.6	1.4	1.4	1.6	1.7
Total	**21.2**	**19.9**	**20.3**	**21.8**	**23.3**

D.2 Efficiency Scenario

Table D.2.1: UK commercial and public sector energy consumption by sub-sector

Sub-sector PJ	2000	2005	2010	2015	2020
Commercial Offices	99	87	92	92	93
Communication and Transport	13	12	12	12	12
Education	118	125	119	115	113
Government	51	46	43	41	40
Health	45	42	40	39	38
Hotel and Catering	149	132	132	133	134
Other	132	114	109	105	103
Retail	160	168	190	215	245
Sport and Leisure	35	30	31	32	33
Warehouses	77	67	63	60	58
Total	**880**	**824**	**830**	**843**	**869**

Table D.2.2: UK commercial and public sector carbon emissions by sub-sector

Sub-sector MtC	2000	2005	2010	2015	2020
Commercial Offices	2.4	1.9	1.9	2.0	2.1
Communication and Transport	0.4	0.3	0.3	0.3	0.3
Education	2.3	2.2	2.1	2.1	2.1
Government	1.3	0.9	0.9	0.8	0.8
Health	0.9	0.8	0.7	0.7	0.7
Hotel and Catering	3.3	2.7	2.6	2.7	2.8
Other	2.9	2.3	2.1	2.1	2.1
Retail	4.8	4.1	4.4	5.2	5.9
Sport and Leisure	0.9	0.7	0.7	0.7	0.7
Warehouses	2.0	1.5	1.3	1.3	1.3
Total	**21.2**	**17.2**	**17.0**	**17.9**	**18.7**

Table D.2.3: UK commercial and public sector energy consumption by end-use

End-use PJ	2000	2005	2010	2015	2020
Catering	89	91	97	103	110
Cooling	26	38	45	51	59
Heating and DHW	567	517	502	496	497
Lighting	128	105	109	114	119
Office Equipment	20	20	21	20	21
Other	49	53	56	59	62
Total	**880**	**824**	**830**	**843**	**869**

Table D.2.4: UK commercial and public sector carbon emissions by end-use

End-use MtC	2000	2005	2010	2015	2020
Catering	2.5	2.1	2.2	2.4	2.6
Cooling	1.0	1.1	1.2	1.4	1.7
Heating and DHW	10.5	9.2	8.8	8.8	8.8
Lighting	4.8	2.9	2.9	3.2	3.4
Office Equipment	0.8	0.6	0.6	0.6	0.6
Other	1.6	1.4	1.4	1.5	1.6
Total	**21.2**	**17.2**	**17.0**	**17.9**	**18.7**

D.3 Policy Scenario

Table D.3.1: UK commercial and public sector carbon emissions by sub-sector

Sub-sector MtC	2000	2005	2010	2015	2020
Commercial Offices	2.4	2.3	2.4	2.7	2.9
Communication and Transport	0.4	0.3	0.3	0.3	0.3
Education	2.3	2.5	2.4	2.4	2.5
Government	1.3	0.9	0.8	0.8	0.8
Health	0.9	0.8	0.7	0.7	0.7
Hotel and Catering	3.3	3.0	3.0	3.2	3.4
Other	2.9	2.6	2.5	2.5	2.6
Retail	4.8	4.1	4.5	5.4	6.2
Sport and Leisure	0.9	0.7	0.8	0.8	0.9
Warehouses	2.0	1.5	1.4	1.4	1.4
Total	**21.2**	**18.7**	**18.8**	**20.4**	**21.8**

Table D.3.2: UK commercial and public sector carbon emissions by end-use

End-use MtC	2000	2005	2010	2015	2020
Catering	2.5	2.0	2.1	2.3	2.4
Cooling	1.0	1.1	1.2	1.5	1.8
Heating and DHW	10.5	10.0	10.0	10.6	11.2
Lighting	4.8	3.5	3.4	3.8	4.0
Office Equipment	0.8	0.7	0.7	0.8	0.8
Other	1.6	1.3	1.4	1.5	1.6
Total	**21.2**	**18.7**	**18.8**	**20.4**	**21.8**

Glossary of Terms

3TC	Three Time Constant
BRECSU	Building Research Energy Conservation Support Unit
CCGT	Combined Cycle Gas Turbine
CCL	Climate Change Levy
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CTN	Confectioners, Tobacconists and Newsagents
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department for Environment, Transport and the Regions
DHW	Domestic Hot Water
DTI	Department for Trade and Industry
DTLR	Department for Transport, Local Government and the Regions
EAC	Equivalent Annual Cost
ECA	Enhanced Capital Allowance
EEBPP	Energy Efficiency Best Practice Programme
EP68	Energy Paper 68 (DTI Energy Projections for the UK)
GDP	Gross Domestic Product
GJ	Giga-Joules (10^9 Joules)
HVAC	Heating, Ventilation and Air Conditioning
IPCC	Intergovernmental Panel for Climate Change
IPPC	Integrated Pollution Prevention and Control
LCD	Liquid Crystal Display
MtC	Million tonnes of Carbon
NAC	Net Annual Cost
N-DEEM	Non-Domestic building Energy and Emissions Model
PJ	Peta-Joules (10^{15} Joules)
SIC	Standard Industrial Classification

T12	38mm fluorescent tubes for lighting
T8	26mm fluorescent tubes for lighting
T5	16mm fluorescent tubes for lighting
VSA	Valuation Support Agency
VSD	Variable Speed Drive