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Sustainable
Development Unit

NHS England
Marginal Abatement Cost Curve

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AEA

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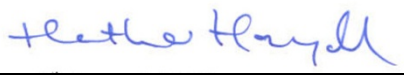
AEA group
329 Harwell
Didcot
Oxfordshire
OX11 0QJ

t: 0870 190 6487
f: 0870 190 6318

AEA is a business name of AEA Technology plc

AEA is certificated to ISO9001 and ISO14001

Author	Name	Tom Hazeldine, Will Clark, Laura Deller and Vasileios Paschos
Approved by	Name	Heather Haydock
	Signature	
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Executive Summary

Aim of the Report

Our aim is to show NHS managers and staff how to save money and cut carbon across the entire health sector.

The NHS Sustainable Development Unit, in conjunction with AEA, believes the Marginal Abatement Cost (MAC) Curve is a powerful tool to collate and illustrate a vast amount of data in a meaningful way to NHS colleagues. It indicates the win-wins where cutting carbon saves money and puts into perspective those measures where the investment costs cannot be recouped. It shows where the most cost efficient and largest CO_2 savings can be made.

In essence it illustrates sensible ways to be prudent with finances, with resources and with the environment. This has the added benefits of improving energy security, improving the health of the population, and making the organisation fit for the future.

This report aims to draw attention to the range of options or carbon reduction measures that the NHS has, including:

- which actions can save money, as well as CO_2, over their life-time;
- how the actions might compare in terms of both tonnes of CO_2 saved and cost-effectiveness.

Specifically, the report was commissioned by the NHS Sustainable Development Unit with support from the Department of Health to:

- Raise awareness amongst senior decision makers of available CO_2 saving measures;
- Illustrate that many CO_2 reduction measures will save money;
- Illustrate that MAC Curves can be used to show savings from many areas and not solely energy savings;
- Demonstrate the usefulness of 'Marginal Abatement Cost Curves' (MAC Curves) to individual NHS Trusts, as a means of ranking options and informing decisions.

Although the intention was not to provide decision makers with a detailed and comprehensive assessment of potential savings, the report does give a sense of scale. It highlights savings totalling between £100m-£200m per year, along with almost 1 million tonnes of CO_2.

Approach

This is a high level report. For simplicity it summarises possible options for four categories of Trusts: Small/Medium Acute Trusts; Large Acute Trusts; Non-Acute Trusts; Ambulance Trusts. The report also includes an NHS wide MAC Curve.

The results are therefore not intended to be definitive. They are indicative, although the assignment was undertaken in consultation with a specially convened NHS Stakeholder Group to ensure the results are as well-grounded as possible. They are representative of the sort of actions individual Trusts could usefully consider, but cannot allow for the detail of particular Trusts, sites, and buildings.

The report seeks to be as transparent as possible about the methodology, data, and assumptions. This is so that, despite being only indicative, it may help individual Trusts think about how they could approach their own detailed assessment.

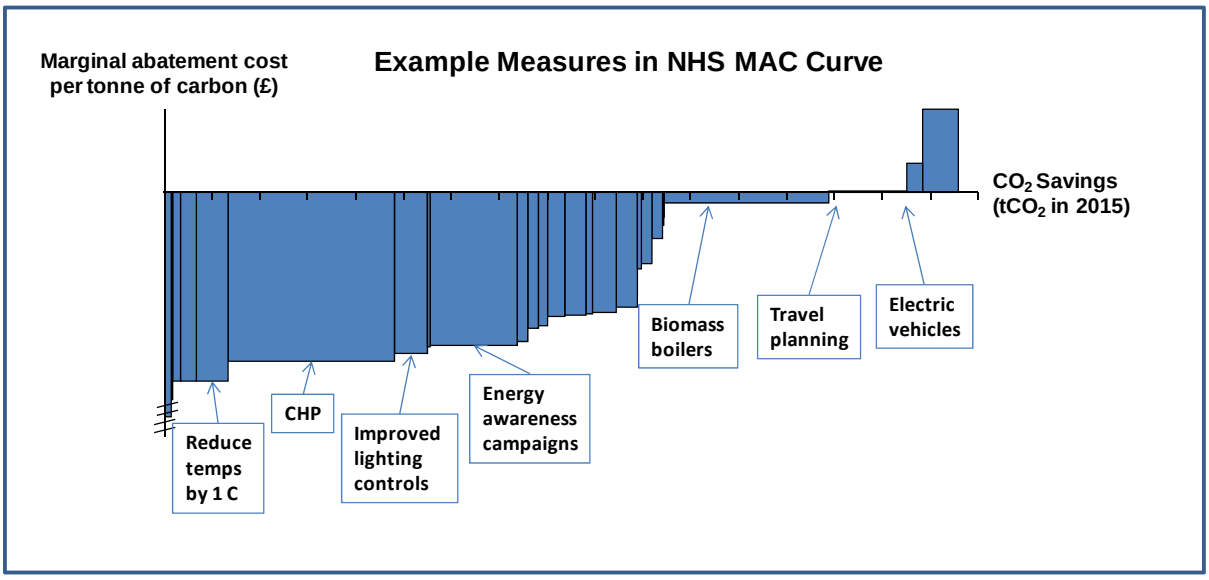
MAC Curves

This report uses the best available data utilising an internationally accepted methodology.

The results are summarised and presented in a series of MAC Curves. These are a means of ranking the various carbon reduction measures in terms of:

- quantity of CO_2 saved;
- cost effectiveness (saving, or cost, per tonne of CO_2 reduced).

In the case of the overall MAC Curve for the NHS, some example measures are:



MAC Curves can also allow the effect of the cost of carbon, e.g. in the Carbon Reduction Commitment Energy Efficiency Scheme. The results in this report do not include such costs, but they would simply have the effect of moving the horizontal axis upwards and making more measures cost effective.

Measures Related to Energy Use

Most measures reviewed in this report refer to the supply and demand use of energy - for heating and lighting buildings, powering equipment, and transport.

The results suggest that the majority of these measures could be cost-effective, although details would depend on the specifics in individual Trusts and buildings. Clearly Combined Heat and Power (CHP) scores well on both axes (potential CO_2 savings and cost-effectiveness). The large range of cost-effective options includes both equipment replacement and behaviour change.

The option of switching to CHP (typically from simple gas-fired boilers) raises another point typical of those high-lighted by the MAC Curve approach. Both CHP and simple biomass boilers are options for improving on gas fired boilers. However, you must not claim the potential savings from both measures. The approach ensures that these ‘overlaps’ are avoided. It also helps decision makers

think about their fundamental objectives, for instance whether to chose the one that is most cost-effective in terms of £/tonne CO_2, or the one that saves most CO_2 but may be less cost-effective. Similarly the process takes account of 'interactions'. This avoids, for instance, claiming the full CO_2 savings from just installing more efficient boilers, if one is also assuming the installation of improved insulation which would reduce the energy demand.

'Non-energy' Related Savings

This is arguably one of the most important issues raised by this indicative analysis.

The NHS calculates its carbon footprint not only in building, transport and energy usage terms, but it also includes carbon embedded in the products and services it procures.

As an example this report takes into account the carbon embedded in such areas as patient travel and drugs procurement. The report has taken the existing data for the annual cost of drugs and assumes a reduction, via reducing drugs wastage, of five percent. A five percent reduction was chosen as an arbitrary figure by the NHS Sustainable Development Unit. The Unit feels that reducing wastage by this level is a possibility since such levels of savings can be achieved in private and public sectors when efficiencies need to be made. Logically it presumes that the drugs sector is therefore 95% efficient. Some may argue that a five percent reduction may be too radical or not evidence based, but the SDU wished this report to stimulate thinking into new possibilities. The details of how such a reduction could be made have not been investigated in this report but such a reduction may well need to be strived for (or even exceeded) if the NHS is to meet its legal obligations for CO_2 reduction over the coming decades. This measure is not included in the above MAC Curve because of lack of specific data. However, a MAC Curve with this illustrative measure is shown in Appendix 2.

The MAC Curve above shows that, ignoring any implementation costs, and using the pro-rata procurement cost reduction, operational measures such as reducing drugs wastage could be far more cost-effective than direct energy related measures.

The quantity of CO_2 saved, for the particular drug wastage assumption used, is in the mid-range of other measures on the MAC Curve. However, the cost-effectiveness (saving per tonne) is so large that the measure is a major contributor to overall savings in terms of absolute £ (tonnes saved x £ saved per tonne).

The fundamental point raised therefore is that, although all the measures discussed in this report would save perhaps almost 1 million tonnes of CO_2 per year, much more will have to be saved to achieve the reductions targeted for 2020. It will be important to include in future analyses a larger range of 'non-energy' operational measures, which could save both money and significant carbon. This might prove more cost-effective than including further energy related measures.

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Appendices

1 Introduction

This report provides a detailed description of the methodologies employed during the NHS Marginal Abatement Cost Curve (MACC) project. It also presents a detailed set of results including the costs and carbon dioxide (CO_2) reductions for each option/carbon reduction measure considered in the MAC Curves. It is comprised of the following sections:

1. Introduction
2. Detailed methodologies
3. Detailed results

1.1 What is a MAC Curve?

A MAC Curve allows the user to compare the cost-effectiveness of carbon dioxide (CO_2) reduction options in the context of CO_2 emissions savings. In other words, a single graph allows users to compare options both in terms of cost effectiveness and CO_2 reductions.

1.2 Overarching aims of the project

The overarching aims for the NHS MAC Curve project are to:

- Raise awareness among senior decision makers of the types of CO_2 saving measures available
- Illustrate that many CO_2 reduction options save money
- Illustrates that MAC Curves can be used to show savings from many areas and not solely energy savings;
- Demonstrate the usefulness of MAC Curves to individual NHS Trusts

To that end, the results of the project are intended to be indicative. The project is <u>not</u> aiming to produce a definitive set of costs and benefits for the selected CO_2 reduction measures. As described in Section 3.2, it is hoped this project will inspire individual NHS Trusts to develop MAC Curves that are specific to their circumstances.

1.3 Scope of the project

The project has considered four categories of NHS Trust in England:

1. Small/Medium Acute Trusts
2. Large Acute Trusts
3. Non-acute Trusts and Primary Care Trusts
4. Ambulance Trusts

These categories of NHS Trust correspond to the Trust types in the ERIC (Estates Return Information Collection) data sets. The categories are characterised in Section 2.3. General Practices (GPs) have not been included in the study due to a lack of baseline data for energy use in buildings.

The project considered three emissions sources:

1. Energy use in buildings
2. Transport
3. Procurement

This is consistent with the original Carbon Footprint of the NHS developed by SEI/ARUP on behalf of the NHS Sustainable Development Unit (SDU) and updated more recently to include 2007 data[1].

1.4 What is the purpose of this report?

This report serves a number of purposes.

- To ensure that the project results are as transparent as possible by presenting the methodologies, data and assumptions that underpin the MAC Curves.
- To show individual trusts how they can identify opportunities to save money by implementing carbon saving measures. Whilst the approach to developing a MAC Curve for an individual Trust will differ in certain respects, most of the key themes will be very similar.
- To show that MAC Curves are not only good for visualising energy savings but are also an excellent tool for illustrating efficiencies across the entire NHS Sector

Therefore, this report will provide an NHS Trust with an insight into the types of data required and the calculations needed to produce its own MAC Curve.

[1] http://www.sdu.nhs.uk/page.php?page_id=93 for original report and http://www.sdu.nhs.uk/page.php?page_id=160 for update.

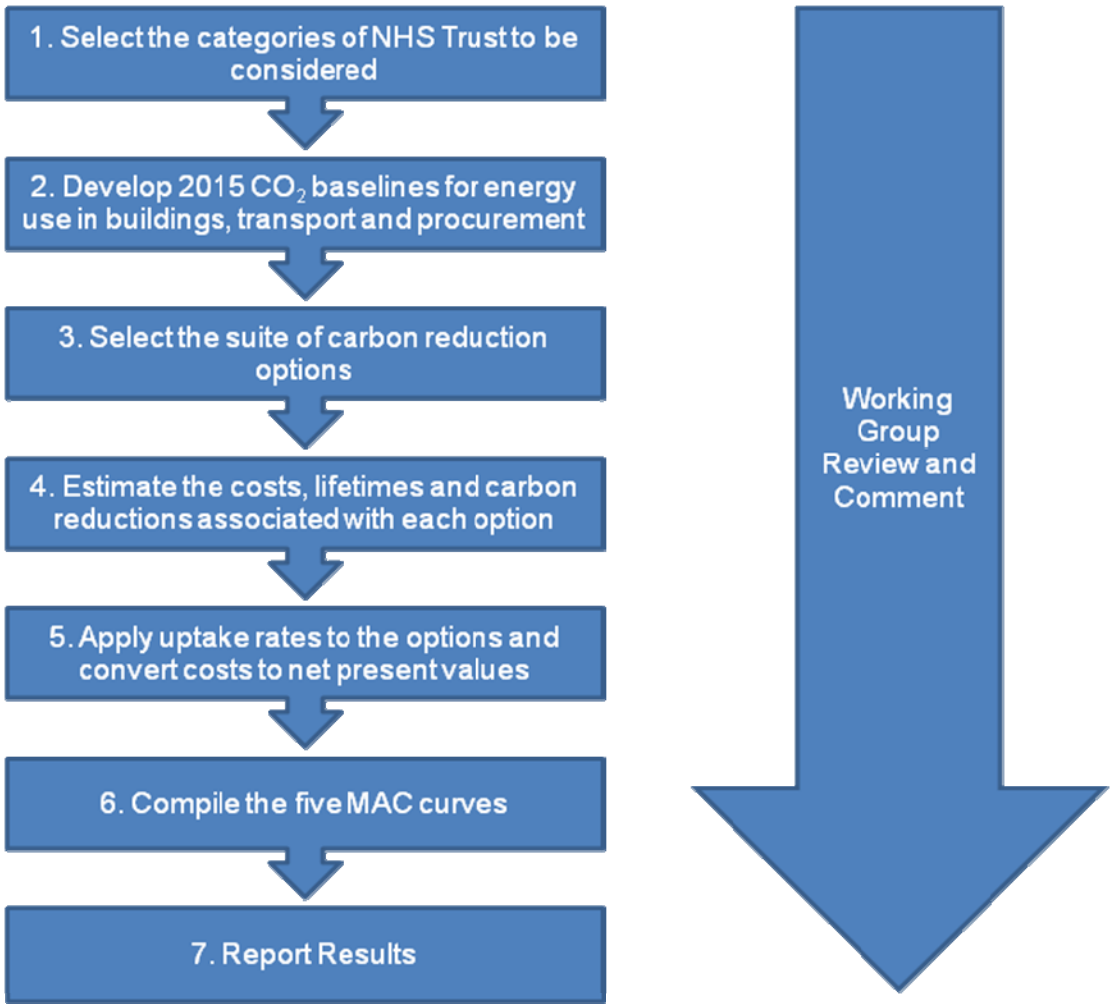
2 Methodology

This section describes the methodologies AEA employed throughout the project from creating the CO_2 baselines to presenting the results in the form of a MAC Curve. AEA and the SDU hope this section will illustrate how individual NHS Trusts can create their own MAC Curves. It is also intended to ensure that the project is as transparent as possible. The assumptions made by AEA whilst compiling the MAC Curve can be found in Appendix 2.

2.1 Overview of AEA's approach

AEA's approach to developing the MAC Curves consisted of seven steps, including reporting, which are illustrated in Figure 1.

Figure 1 – An overview of AEA's approach



The remainder of this section explains each of these steps in more detail.

2.2 The Stakeholder Group

The Stakeholder Group (see below) played a crucial role in the project by acting as a sounding board for AEA's ideas, reviewing AEA's proposed approaches, providing data sets and helping to fill gaps in data sets. The Stakeholder Group also provided guidance on how to present the outputs from the project and the sort of information that NHS managers 'on the ground' would find useful. The final element of the Stakeholder Group's involvement was to review the draft of this report.

AEA engaged with the Stakeholder Group via two structured teleconferences, one-to-one telephone conversations and email correspondence.

The members of the Stakeholder Group were selected to provide expertise across the emissions sources and categories of NHS Trust being considered during the project. The Stakeholder Group made suggestions and offered comments but ultimately it is the NHS Sustainable Development Unit and AEA who are responsible for the final content of this report. The Stakeholder Group comprised of:

- Sonia Roschnik (Operations Director, NHS SDU)
- Imogen Tennison (Information Analyst, APHO lead areas)
- Chris Holme (Principal Engineer, Department of Health)
- Gavin Roberts (Economics Advisor, Department of Health)
- David Wathey, (Head of Sustainable Procurement, Department of Health)
- Martin Stott (Green Group Chairman, Lincolnshire Partnership NHS Foundation Trust)
- Andrew Sanders (Associate Director of Estates, Addenbrookes Hospital)
- Jug Johal (Head of Transport, Car Parking and Security, North Lincolnshire and Goole NHS Trust)
- John Hehir (Business Planning Manager, North East Ambulance Service NHS Trust)
- Stuart Moulder (Interim Head of Property, East of England Ambulance Service NHS Trust)

2.3 Selecting the four categories of NHS Trust

One of the themes throughout the project has been the use of four categories of NHS Trust to represent the range of Trust types that exist within the NHS. This sub-section will explain the rationale for that approach and characterise the four categories.

2.3.1 Why were four categories developed?

The aims of this project are to:

- raise awareness of potential CO_2 reduction measures among senior decision makers
- illustrate many measures save money
- demonstrate the usefulness of MAC Curves

With those aims in mind AEA needed to find a way of analysing the 10 NHS Trust types defined in the ERIC return in a robust manner, whilst considering a range of emissions reduction options and showcasing MAC Curves.

In an effort to balance these competing aims, AEA decided to combine the ten ERIC categories to create four broadly similar categories. This approach allowed the AEA team to consider a significant number of emissions reduction options - 10 to 18 depending on the category. As a result AEA were able to illustrate how MAC Curves can be used to present a swathe of information in an easily digestible form.

The alternative would have been to consider around five or six measures for each of the 10 categories. However, AEA felt this latter approach would have been of limited use to individual Trusts in terms of inspiring ideas for CO_2 reduction. In addition, it would not have shown MAC Curves in their best light since they are at their most useful when comparing a larger number of options.

2.3.2 Creating the four categories of NHS Trust

The most recent ERIC data set splits NHS Trusts in England and Wales into 10 categories. These categories are defined in the document 'Clusters Summary 2008-09'. As described above, it was necessary to split these into four categories:

1) **Small / Medium Acute Trusts**
   Small Acute Trusts
   Medium Acute Trusts
   Multi-Service Acute Trusts
   Specialist Acute Trusts

2) **Large Acute Trusts**
   Large Acute Trusts
   Teaching Acute Trusts

3) **Non-acute Trusts / Primary Care Trusts**
   Care Trusts
   Mental Health and Learning Disability Trusts
   Primary Care Trusts

4) **Ambulance Trusts**
   Ambulance Trusts

As far as possible, AEA designed the project so that the different categories of NHS Trusts had a broadly similar carbon footprint profile. In other words, the split of CO_2 emissions by end use (energy use in buildings, transport and procurement) should be similar for the NHS Trust types in each of the four categories. To achieve this consistency AEA took account of the likely size of the buildings, nature of activities/services and age of buildings when compiling the categories. Inevitably this involved an element of compromise but the approach ensured that the overall estimates of CO_2 saving potential were as accurate as possible.

It should be noted that this generalisation will overlook specific opportunities at certain Trusts which will be determined by their location and size, and the age and condition of building stock. The MACC approach gives a good indication of the likely measures that can deliver emissions reductions at the lowest cost, but is no substitute for site audit and the development of individual business cases. There is also a strong case for Trusts to develop their own MAC Curves tailored to their individual circumstances and opportunities.

In addition Trusts will have to take their own circumstances into account when planning the implementation of measures, including likely disposal and decommissioning of buildings and the length of time left to run on leases where buildings are not owned. This is especially important when measures have long payback periods (independent of their Net Present Value) as it is possible that payback might not be achieved within the useful life of the building or lease.

2.3.3 Characterising the four categories

This sub-section will characterise each of the categories to allow individual Trusts to decide which category best matches their circumstances and hence which MAC Curve is of most relevance.

Table 1 was derived from the 2008/09 ERIC data set. The information provided in Table 1 gives an indication of the fuel usage in buildings in different Trust categories. Carbon dioxide (CO_2) emissions from energy use in buildings make up about 22% of the overall carbon footprint of the NHS, with transport emissions at 18% and procurement at 60%[2].

[2] SEI/ARUP – NHS England Carbon Emissions: Carbon Footprint Emissions Modelling to 2020, January 2009

Table 1 – Characteristics of each of the four categories of NHS Trust considered in the project

Categories of NHS Trust	Average floor area (m^2)	Average number of buildings	Average number of employees	Average annual electricity consumption (GJ)	Average annual gas consumption (GJ)
Small/Medium Acute	65,080	3	2,259	33,774	74,846
Large Acute	170,420	7	5,480	86,084	232,593
Non-Acute and PCT	39,136	67	1,594	11,869	29,084
Ambulance	44,870	80	3,023	19,067	29,009

2.4 CO_2 baseline methodologies

This sub-section describes the methodologies employed by AEA to create the 2015 CO_2 baselines for energy use in buildings, transport and procurement. The CO_2 baselines were a key element of the MAC Curve since the CO_2 savings for each of the CO_2 reduction options will be expressed as a percentage of part of these baselines. For instance, one CO_2 reduction measure could be the introduction of a more energy efficient lighting system. The CO_2 savings associated with that measure would be expressed as a percentage of the electricity element of the energy use in the buildings baseline.

2.4.1 Data

There are different levels of accuracy in the baseline emissions. In general, direct emissions such as emissions from heating, lighting and business travel can be more accurately estimated than indirect emissions such as those from patient travel or procurement. The degree of uncertainty on procurement is particularly high because these are embedded CO_2 emissions, i.e. emissions from the original manufacture and transport of those products, rather than in-use emissions. Gaps exist in, for example:

- Trust-level CO_2 baseline data for transport or procurement
- Data on energy use in GPs surgeries
- The Electronic Staff Record (ESR) data set for business travel (due to the fact it is an optional field)

However, there were some notable exceptions to this lack of NHS-wide data sets, such as the ERIC database[3] and HES-online database[4].

Where there were gaps in the data sets AEA tailored the baseline methodologies in response to these challenges. For instance, when the Royal Society of General Practitioners confirmed that there was no central database of energy use in GPs' surgeries, AEA and the SDU chose to exclude GPs from the analysis. In addition, journeys to and from GPs' surgeries were removed from the patient travel element of the transport baseline. It has also been assumed that each Trust's contribution to the overall NHS carbon footprint remains constant to 2015. That is to say that if a Trust contributed 0.25% to the baseline it is assumed that it contributes 0.25% in 2015.

The most significant data limitation in terms of the impact on project was related to the lack of Trust-level CO_2 baseline data for transport and procurement. The SEI/ARUP carbon footprint of the NHS featured an estimate of the 2015 CO_2 baseline for transport and procurement. These baselines were compiled using a 'top-down' methodology. Whilst that is a useful first step it does not split down the baseline to a Trust-level. The only way for AEA to reach Trust-level figures would have been to use a

[3] http://www.hefs.ic.nhs.uk/Home.asp
[4] http://www.hesonline.nhs.uk/Ease/servlet/ContentServer?siteID=1937

proxy. Using a proxy would have entailed assuming that the distribution of CO_2 emissions amongst the Trusts mirrored the distribution of another parameter. So, taking transport as an example one of AEA's suggested proxies was the number of car parking spaces. Therefore, the CO_2 emissions from transport would have been allocated to each of the Trusts on the basis of the number of car parking spaces. However, several members of the Stakeholder Group strongly disagreed with the proxies approach. There was a consensus that none of the available proxies would be suitable to distribute the CO_2 emissions. There was also a feeling that it was one layer of assumptions too many and as such the results would lack credibility.

In response AEA decided that Transport and Procurement should only be considered at an NHS-level. In other words, no attempt would be made to split the CO_2 baselines for transport and procurement down to a Trust-level. This approach yielded 5 separate MAC Curves (which are illustrated in Section 3.1):

- Four 'Trust-level' MAC Curves, one for each of the four categories of NHS Trust considered during the project. These MAC Curves are focused exclusively on energy use in buildings measures. Transport and procurement measures would not feature on these MAC Curves. These MAC Curves would provide users with an insight into the most cost effective measures for each category of NHS Trust.

- In addition, a single NHS-level MAC Curve has been compiled where the CO_2 reduction measures are grouped by type. For example, all the lighting measures would be grouped together, all the CHP measures would be grouped together etc. Crucially, this high-level MAC Curve would also feature some simple transport and procurement measures. For example, these measures might include green travel plans and reducing packaging for medical equipment. They would be presented in terms of percentage reduction in NHS transport and NHS procurement. In other words, no attempt would be made to quantify CO_2 savings or costs at a Trust-level. This MAC Curve would provide a summary of the scale and cost effectiveness of groups of measures across the NHS in England.

AEA hopes that such a pragmatic approach will avoid the potentially divisive issues around splitting the transport and procurement baselines down to a Trust-level. In turn, it is expected that the results will have the broadest possible support from stakeholders.

It should be noted that transport and procurement options are addressed at the NHS level only because of data limitations, i.e. an inability to disaggregate some national data to Trust level. However, these measures could be implemented by individual Trusts or groups of Trusts.

2.4.2 Energy use in buildings CO_2 baseline

AEA's approach to 'Energy use in buildings' for all four categories[5] of NHS Trusts yielded a 2015 CO_2 baseline[6] which was split into 2 main elements:

- Fossil fuel (which predominantly consisted of natural gas with some fuel oil)

- Electricity

AEA's approach consisted of four main steps:

1) Extracting the 2015 CO_2 emissions projection for energy use in buildings from the SEI/ARUP projections[7]. These projections were split into fossil fuel use and electricity use.

2) The SEI/ARUP projections were split down to a Trust-level using the 2008-09 ERIC return. This was achieved by assuming that each NHS Trust's percentage contribution to the overall NHS England energy consumption remains constant between 2008/09 and 2015. In other

5 Small / Medium Acute Trusts, Large Acute Trusts, Non-acute Trusts / Primary Care Trusts, Ambulance Trusts
6 The baseline considered 'in use' energy only and does not account for the embedded emissions in materials used in construction or vehicles etc.

words, if a particular NHS Trust contributes 0.25% of the total NHS England energy consumption from buildings in 2008/09, it will assumed to make a 0.25% contribution in 2015.

3) For each of the four NHS Trust categories, the Trust-level energy use from buildings was aggregated. That calculation gave a total value of 'fossil fuel use' and 'electricity use' (both in kWh) for each of the four NHS Trust categories.

4) Finally, the values for total fossil fuel use and total electricity use were converted to tonnes of CO_2 using the appropriate emission factors from the 2009 Defra Company Reporting Guidelines[8].

2.4.3 Transport CO_2 baseline

The transport CO_2 baseline comprised four elements:

- Patient travel
- Visitor travel
- Staff travel (commuting)
- Staff travel (business travel)

Appendix 2 gives details of the various assumptions and data sources used for each of these elements.

2.4.4 Procurement CO_2 baseline

AEA used the baseline for procurement emissions provided in the SEI/ARUP report for the indicative drugs wastage reduction measure discussed in Appendix 2. The baseline for drugs procurement was derived from the costs associated with procurement of pharmaceuticals in 2004, a projection of future expenditure and a value for CO_2 per £ spent. The latter value has been subject to some discussion as it is based on average data from input-output tables and does not fully reflect issues such as the use of generic drugs or potential health impacts. Further details are provided in the SEI/ARUP report[7].

2.5 CO_2 reduction measures

For each of the four categories of NHS Trust, AEA developed a suite of options for reducing CO_2 emissions from energy use in buildings. AEA also developed a small number of options for reducing CO_2 emissions from transport and procurement activities. These latter options were only considered at an NHS-level. This sub-section lists the options before explaining further:

- How the options were selected
- How the costs and CO_2 savings were estimated
- The sequence of calculations used to generate the MAC Curve
- The assumptions made during the course of the calculations

Improved space efficiency (i.e. providing the same level of health benefits with a smaller floor area) has been excluded from this analysis. However individual Trusts may identify opportunities to pursue this measure. We would encourage this within an appreciation of any potential health consequences of such a move.

These options are defined in Table 2 along with guidance as to which MAC Curve/s they appear in.

[8] http://www.defra.gov.uk/environment/business/reporting/pdf/20090928-guidelines-ghg-conversion-factors.pdf

Table 2 – CO_2 emissions reduction options developed by AEA

Option	MACCs that include this option				
	Small/medium acute	Large acute	Non-acute and PCT	Ambulance	NHS Level
Energy efficient lighting	X	X	X	X	X
Improve lighting controls	X	X	X		X
Energy awareness campaign	X	X	X	X	X
Turn down thermostat by 1 degree C	X	X	X		X
Improve efficiency of steam plant or boiler plant	X	X	X		X
Biomass boiler	X	X	X		X
Decentralisation of hot water boilers			X		X
Conventional boiler replacement				X	X
Office electrical equipment improvements			X		X
Improve the efficiency of chillers	X	X			X
Building management system optimisation	X	X	X		X
Improve heating controls	X	X	X		X
Roof insulation	X	X	X		X
Wall insulation	X	X	X		X
Improve building insulation levels				X	X
Insulation - window glazing and draught proofing	X	X	X	X	X
Improve Insulation to pipework, and/in boiler house	X	X	X	X	X
Voltage optimisation			X		X
Variable speed drives	X	X			X
Voltage optimisation	X	X			X
Combined heat & power	X	X			X
Solar hot water	X	X	X		X
Wind turbine	X	X	X		X
Travel planning					X
Electrification of vehicles					X
Teleconferencing replacing travel					X
Reduce packaging					X

More detailed explanations of each measure can be found in Appendix 1.

2.5.1 Selecting the CO_2 reduction options

One of the aims of this project is to alert senior decision makers at an NHS Trust-level that many CO_2 reduction measures/options can save money. With this in mind, AEA focussed on developing a suite of options that could demonstrate significant savings before 2015. In fact, many of the options presented in Section 2.5 would actually payback within two or three years based on typical measures in a typical Trust. In compiling the list of options AEA drew on their experience of working with more than 25 NHS Trusts to reduce energy usage or manage their CO_2 emissions.

The process of selecting the CO_2 reduction options was iterative. AEA presented their initial thoughts at the second Stakeholder Group teleconference and refined the suite of options following the Stakeholder Group's comments. The suite of options was then amended once AEA had fully investigated the availability of cost and CO_2 savings data. Further refinements followed a series of one-to-one conversations with the SDU and individual members of the Stakeholder Group.

Many of the options in the 'energy use in buildings' category were familiar to the NHS energy managers and other NHS stakeholders. Indeed, many of the energy use measures in the building options have already been employed by some of the NHS Trusts. In view of this familiarity, AEA attempted to 'push the boundaries' with their choice of transport and procurement options. Therefore, the transport and procurement options are less likely to have been employed yet by the Trusts and are intended to be significantly more radical than the energy use in buildings measures.

2.5.2 Estimating the costs and CO_2 savings for each option

In a similar vein to the selection of the options, estimating the capital costs, change in operating costs and CO_2 savings associated with each option was an iterative process. AEA compiled initial estimates by drawing on their experience of developing options for reducing energy use and CO_2 emissions at the NHS Trusts. These initial estimates were reviewed by the Stakeholder Group during the second teleconference. AEA amended the costs and CO_2 savings in light of the Stakeholder Group's comments. Further refinements were made after reviewing a range of other data sources:

- Salix
- NHS CO_2 Management Rapid Assessment of Potential Tool – developed by Carbon Trust / Carbon Insight
- An unpublished report commissioned by the Department of Health
- Interim results from work to reduce packaging in the NHS
- CIBSE Guide F

2.5.3 Sequence of MAC Curve calculations

This sub-section provides an overview of the process AEA followed to compile the MAC Curve. The assumptions AEA made during the process are listed in Appendix 2.

1) AEA began by calculating the CO_2 baseline for energy use in buildings, transport and procurement using the methodologies described in Section 2.4.

2) For each option AEA then estimated:

    a) **Capital cost** of implementing the measure

    b) **Change in operating cost** which mainly entailed reductions in fuel consumption. Notable exceptions included green travel plans where there were significant additional costs associated with providing an improved bus service

    c) **Percentage reduction in CO_2 emissions**

    d) **Lifetime of the option** to allow the capital costs to be annualised

    e) **Percentage uptake rate** for each category of NHS Trust in which the option will be implemented[9]

3) Next, AEA calculated the Net Present Value (NPV) of all the costs:

    a) Capital cost

    b) Change in operating cost

4) The next step in the sequence of calculations was to calculate the absolute CO_2 reductions. This was undertaken in two stages. Firstly, by applying the estimated percentage reduction to appropriate portion of the CO_2 baseline. Secondly, by applying an estimated percentage uptake rate. The uptake rate is a measure of the technical potential to implement the option, taking into account the proportion of Trusts that are likely to already have that measure

[9] This could be amended in the future should improved information regarding NHS lease length be obtained

installed. A full list of the assumed uptake rates can be found in Appendix 1.

5) The penultimate step in the sequence of calculations was to calculate the cost per tonne of CO_2 (£/tonne) abated for each option. This is the key metric for the MAC Curve since it is the value that is plotted on the vertical axis (with annual CO_2 savings on the horizontal axis). At this stage, no account had been taken of the interactions and overlaps between measures.

6) The final step was to take account of interactions and overlaps between measures. Interactions concern situations where the carbon savings from a measure are reduced because another measure has been installed previously. For example, savings from more efficient boilers are lower if the building insulation is improved first. Overlaps concern measures that can't be introduced because another (more cost-effective option) has already been adopted. For example, if a gas-fired combined heat and power (CHP) system has been installed then it wouldn't be cost-effective to introduce solar water heating subsequently.

Further details and a worked example of this methodology are given in Appendix 2.

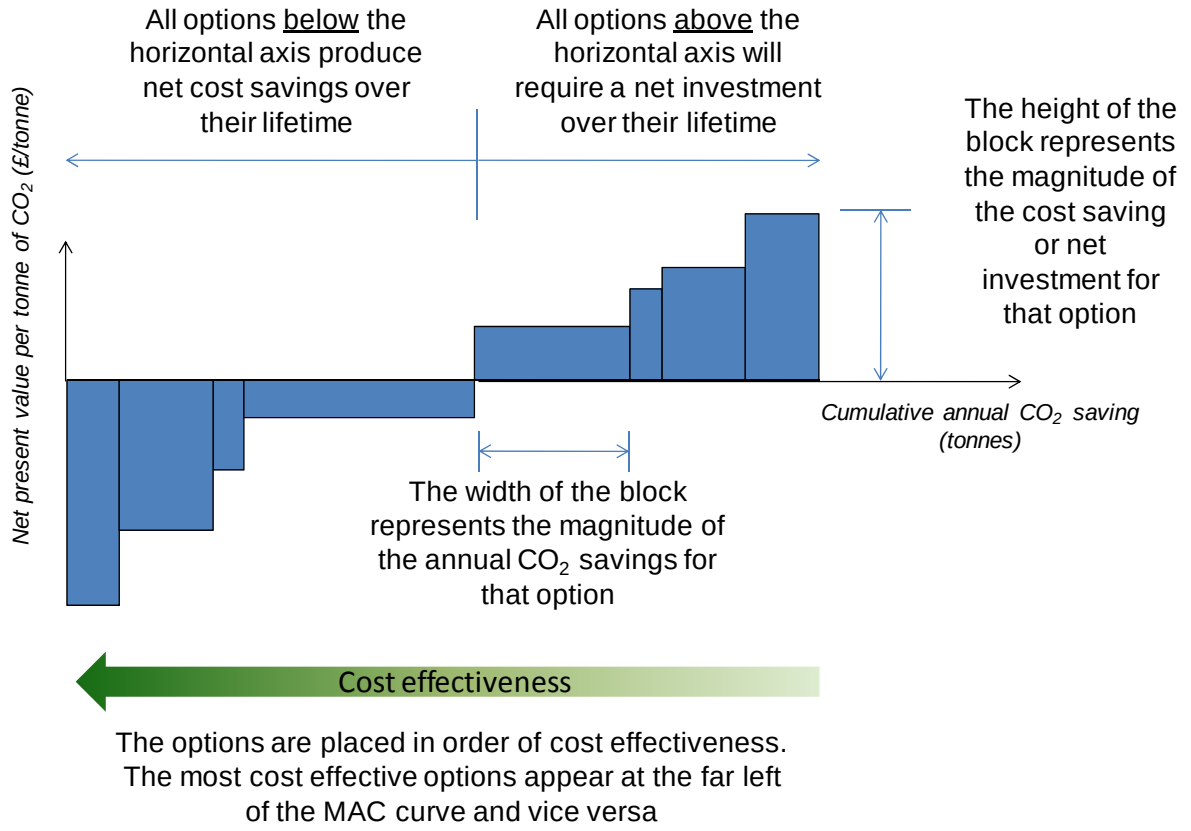
3 Results

This section presents the key results from the project. Five MAC Curves are presented – one for each of the four categories of NHS Trust and an overall MAC Curve for NHS England. The MAC Curves for each category are limited to energy in buildings measures whilst the NHS England MAC Curve includes transport and procurement options.

3.1 MAC Curves

Figure 2 describes how to interpret a MAC Curve. The vertical axis (y-axis) of the Curve shows the cost-effectiveness (£/tCO_2) based on NPV costs and lifetime CO_2 savings while the horizontal axis (x-axis) shows the annual carbon savings. The cumulative annual savings (the full width of all the blocks on the MACC) give an indication of the maximum potential carbon savings in 2015, which can be compared with the baseline and targets for the NHS. The options presented in each MAC Curve are numbered to avoid the MAC Curves becoming too cluttered. The MAC Curve also includes a list of the measures in decreasing order of cost-effectiveness (£/tCO_2) so that the reader can easily identify which option is represented by which block of the MACC.

Figure 2 – An explanation of how to interpret a MAC Curve



Social costs (i.e. external costs and or benefits created as a result of direct expenditure) should also be considered when using a MACC to aid priority setting for investment in the NHS. Research results provided by the Department for Health have shown that for each £1 of additional costs falling on the NHS there is a social cost of £2.40. To determine whether a measure is socially beneficial, the cost per tonne for abatement should be compared to the social cost of carbon, which is currently defined by

Defra at around £26 per tonne. It therefore follows that no measure should be considered if its social costs (NHS costs x 2.4) lead to a marginal abatement cost of more than £26 per tonne. This could be reflected in the MACC by multiplying all costs by 2.4 and adding a cost of carbon of £26/tonne or, more simply, by comparing the unadjusted abatement costs per tonne by the cost of carbon divided by 2.4. On that basis, one would not choose to take up options in the MAC Curve that exceed £10/tCO_2. In practice, given the uncertainties involved in the calculations, the best approach might be not to undertake any measures that result in increased costs, i.e. any measures located above the axis on the MAC Curve.

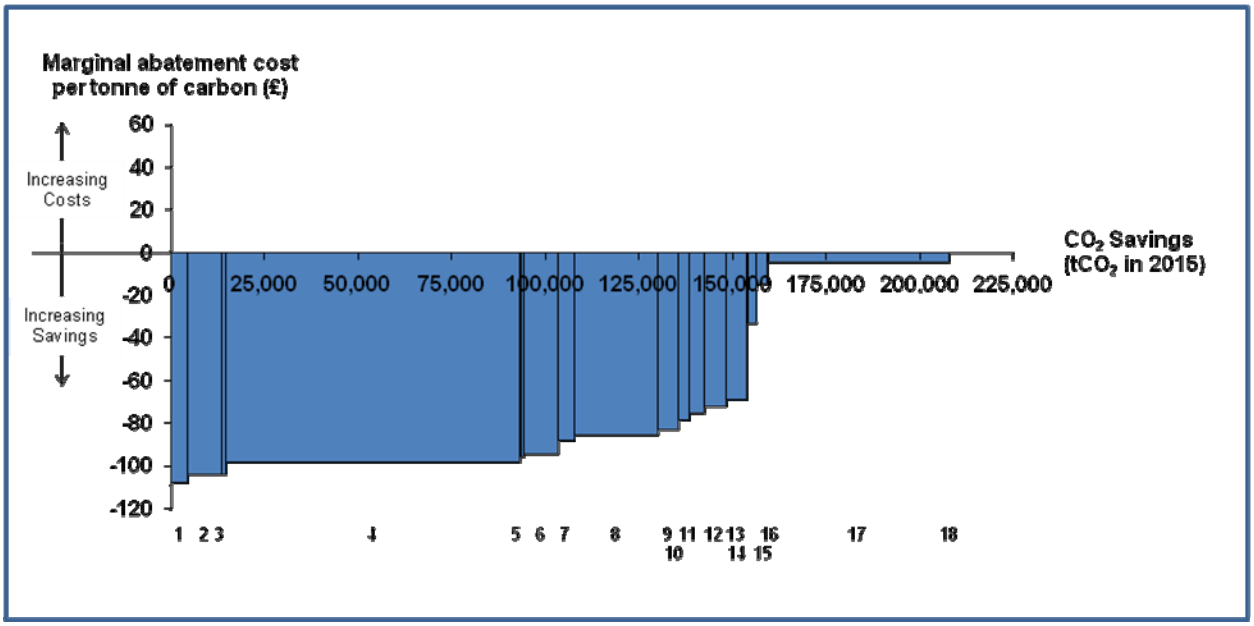
3.1.1 Emissions Trading Schemes – CRC & EU ETS

Where an NHS Trust is required to take part in an emissions trading scheme, either the EU's scheme or the proposed Carbon Reduction Commitment Energy Efficiency Scheme (CRC), the net effect will be to raise the x-axis by the price of carbon within each scheme. This will make more measures cost effective. However, it should be noted that the EU ETS price has shown significant fluctuation in its five years of history and currently it is not clear what the CRC carbon prices might be. As such, Trusts that are exposed to a Carbon Trading regime should take professional advice before trying to moderate any of the Curves shown here to incorporate direct costs of carbon allowances.

3.1.2 MAC Curve for Small/Medium Acute Trusts

Figure 3 shows the MAC curve developed for the Small/Medium Acute Trusts category. As explained above, the MAC curves for individual Trust categories (Figures 3 to 6) do not include transport or procurement options as these are considered later at the NHS level.

Figure 3 – MAC Curve for Small/Medium Acute Trusts Category



Option		£/tCO_2	CO_2 savings (tCO_2 in 2015)
1	Voltage optimisation	-108	4,417
2	1 degree C	-104	9,133
3	Improve the efficiency of chillers	-104	1,242
4	CHP installation	-98	78,615
5	Variable speed drives	-96	828
6	Improve lighting controls	-94	9,110
7	Building management system optimisation	-88	4,517

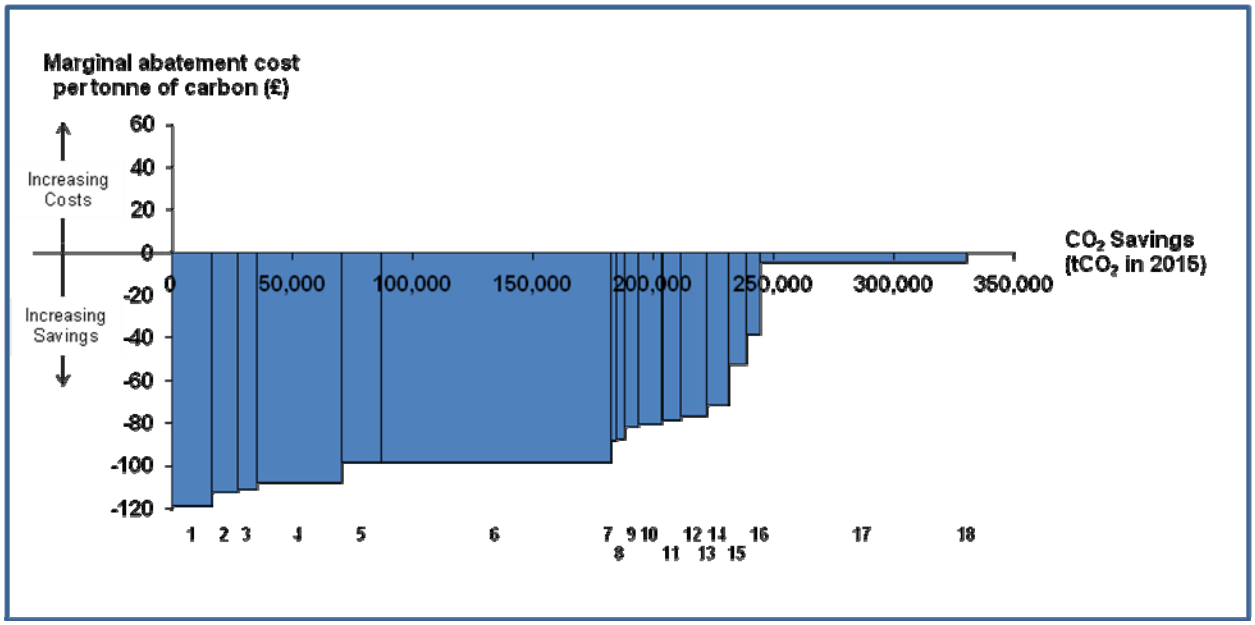
8	Energy awareness campaign	-86	22,077
9	Energy efficient lighting	-83	5,521
10	Improve Insulation to pipe work, and/in boiler house	-79	2,884
11	Improve heating controls	-75	4,110
12	Roof insulation	-72	5,769
13	Wall insulation	-69	5,769
14	Improve the efficiency of steam plant or hot water boiler plant	-65	0
15	Insulation - window glazing and draught proofing	-33	2,404
16	Wind turbine (80kW)	-15	3,075
17	Biomass boiler	-4	48,416
18	Solar hot water	48	0
Total annual CO_2 savings in 2015 – all measures			207,888

For Small/Medium Acute Trusts, there are many cost-effective energy efficiency measures that can be introduced with net cost savings, including changes to technology and to behaviours. The total savings of about 208 $ktCO_2$/yr represent about 20% of the baseline CO_2 emissions from buildings in this Trust category. The measures that offer the greatest potential for savings are combined heat and power (CHP), biomass boilers and energy awareness campaigns. Another cost-effective option for Large Acute Trusts is to turn the thermostat down by 1°C. Clearly this sort of action would need to be considered in the context of patient (and staff) comfort and health. Boiler upgrades and solar water heating have no savings associated with them as we have assumed that existing boilers will be replaced with CHP (option 4) or biomass boilers (option 17) instead. Note this is a different approach to that taken earlier in the study, where improvements to existing gas boilers were made in preference to the introduction of biomass boilers on cost-effectiveness grounds. Our methodology for dealing with interactions and overlaps between measures is described in Appendix 2.

3.1.3 MAC Curve for Large Acute Trusts

The MAC Curve for the Large Acute Trusts Category is shown in Figure 4.

Figure 4 – MAC Curve for Large Acute Trusts Category



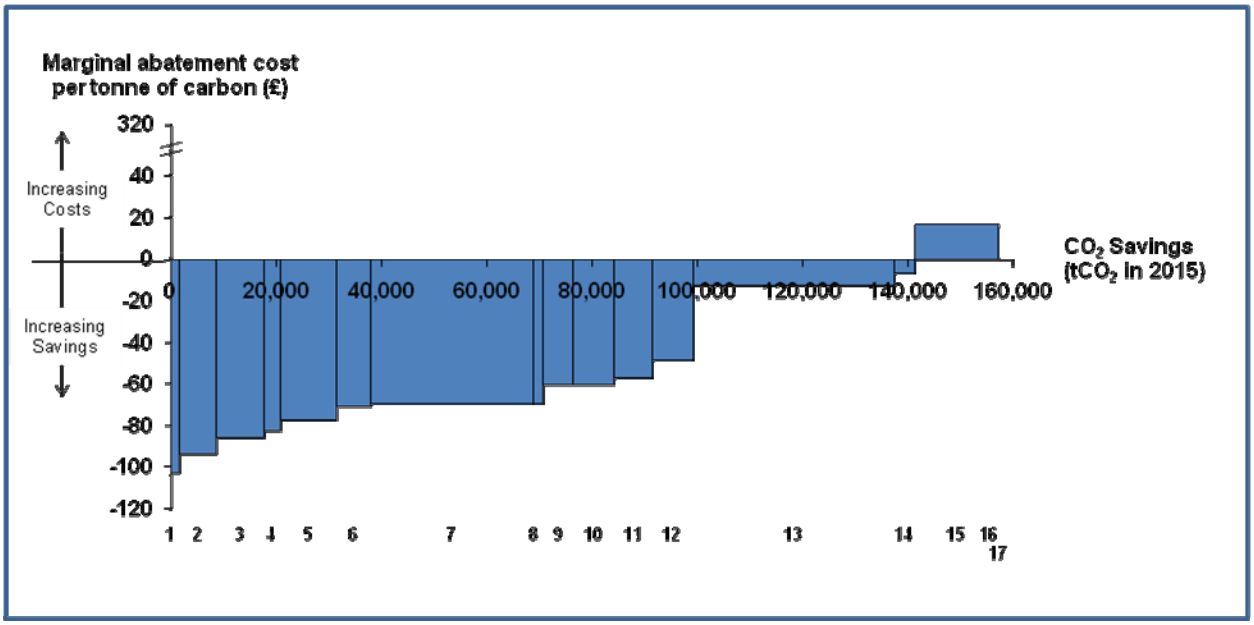
Option		£/tCO$_2$	CO$_2$ savings (tCO$_2$ in 2015)
1	1 degree C	-119	16,555
2	Voltage optimisation	-112	10,821
3	Improve the efficiency of chillers	-111	7,890
4	Energy awareness campaign	-108	35,519
5	Improve lighting controls	-98	16,232
6	CHP installation	-98	95,361
7	Variable speed drives	-88	2,254
8	Building management system optimisation	-88	3,676
9	Improve insulation to pipe work, and/in boiler house	-82	5,518
10	Roof insulation	-81	9,933
11	Improve Heating controls	-78	7,450
12	Wall insulation	-77	11,036
13	Improve the efficiency of steam plant or hot water boiler plant	-72	0
14	Energy efficient lighting	-71	9,018
15	Wind turbine (250kW)	-53	7,643
16	Insulation - window glazing and draught proofing	-38	5,518
17	Biomass boiler	-4	86,019
18	Solar hot water	49	0
Total annual CO$_2$ savings in 2015 – all measures			330,444

A total of about 330 ktCO$_2$/yr of savings have been identified for Large Acute Trusts, nearly all of which can be achieved by introducing cost-effective measures such as improvements in heating and lighting systems. This represents about 18% of the baseline CO$_2$ emissions from buildings in this Trust category. CHP and biomass boilers are the biggest measures, accounting for about 55% of the total savings. As for small/medium acute Trusts, another cost-effective option is to turn the thermostat down by 1°C. Clearly this sort of action would need to be considered in the context of patient (and staff) comfort and health. Also boiler upgrades and solar water heating have no savings associated with them as we have assumed that existing boilers will either be replaced with CHP (option 6) or biomass boilers (option 17) instead. In reality some Trusts may decide to install CHP while others may favour biomass boilers or even solar water heating, depending on their local circumstances and priorities.

3.1.1 MAC Curve for the Non-Acute/Primary Care Trusts Category

The MAC Curve for the Non-Acute/PCTs category is shown in Figure 5.

Figure 5 – MAC Curve for Non-Acute/Primary Care Trusts Category



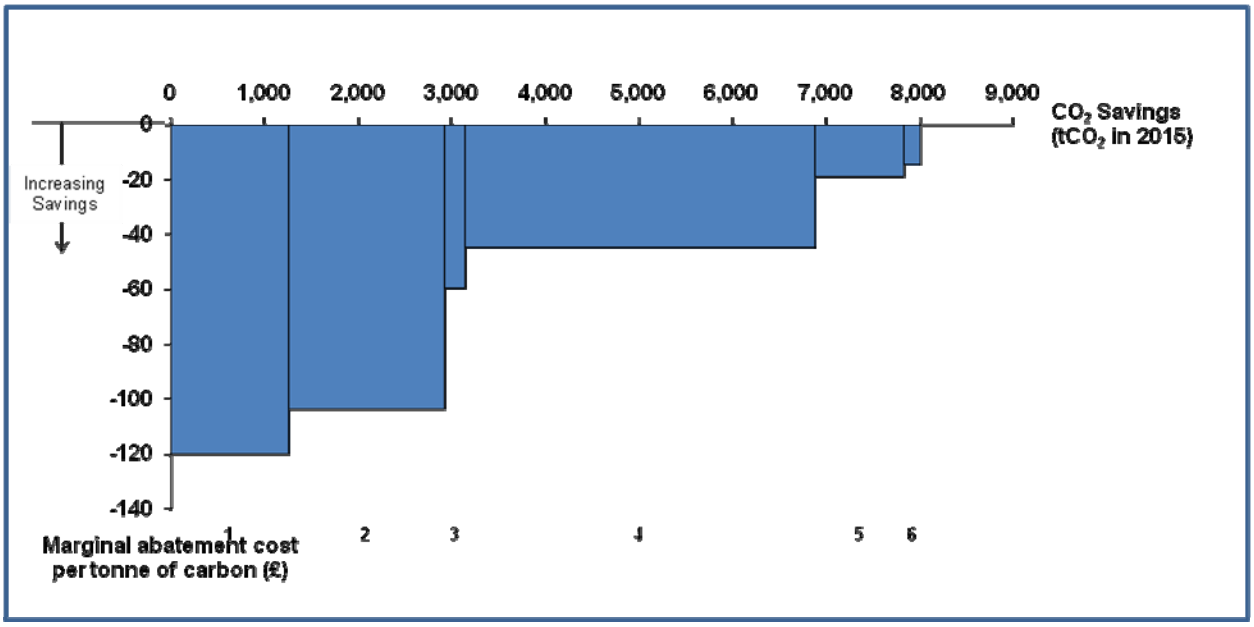
Option		£/tCO$_2$	CO$_2$ savings (tCO$_2$ in 2015)
1	Voltage optimisation	-103	1,590
2	1 degree C	-94	7,075
3	Improve lighting controls	-86	8,944
4	Building management system optimisation	-83	3,327
5	Decentralisation of hot water boilers	-77	10,612
6	Improve the efficiency of steam plant or hot water boiler plant	-71	6,367
7	Energy awareness campaign	-70	30,995
8	Improve insulation to pipe work, and/in boiler house	-69	1,862
9	Improve heating controls	-60	5,660
10	Wall insulation	-60	7,819
11	Roof insulation	-57	7,168
12	Energy efficient lighting	-49	7,751
13	Biomass Boiler	-13	38,288
14	Insulation - window glazing and draught proofing	-7	3,910
15	Office electrical equipment improvements	17	15,900
16	Solar hot water	49	0
17	Wind turbine (10kW)	313	4
Total annual CO$_2$ savings in 2015 – all measures			157,271

For Non-acute Trusts and PCTs, a wide range of cost-effective measures have been identified in buildings; for example, improved voltage optimisation, lighting controls and decentralisation of hot water boilers are amongst the most cost-effective. Wall and roof insulation is also highlighted as offering significant cost-effective savings. Biomass boilers and energy awareness campaigns are the major contributors to the total potential carbon savings. CHP has not been included as an option in this Trust category. The total savings of about 157 ktCO$_2$/yr represent about 20% of the baseline CO$_2$ emissions from buildings in this Trust category.

3.1.1 MAC Curve for Ambulance Trusts

The MAC Curve for the Ambulance Trusts category is shown in Figure 6.

Figure 6 – MAC Curve for Ambulance Trusts Category



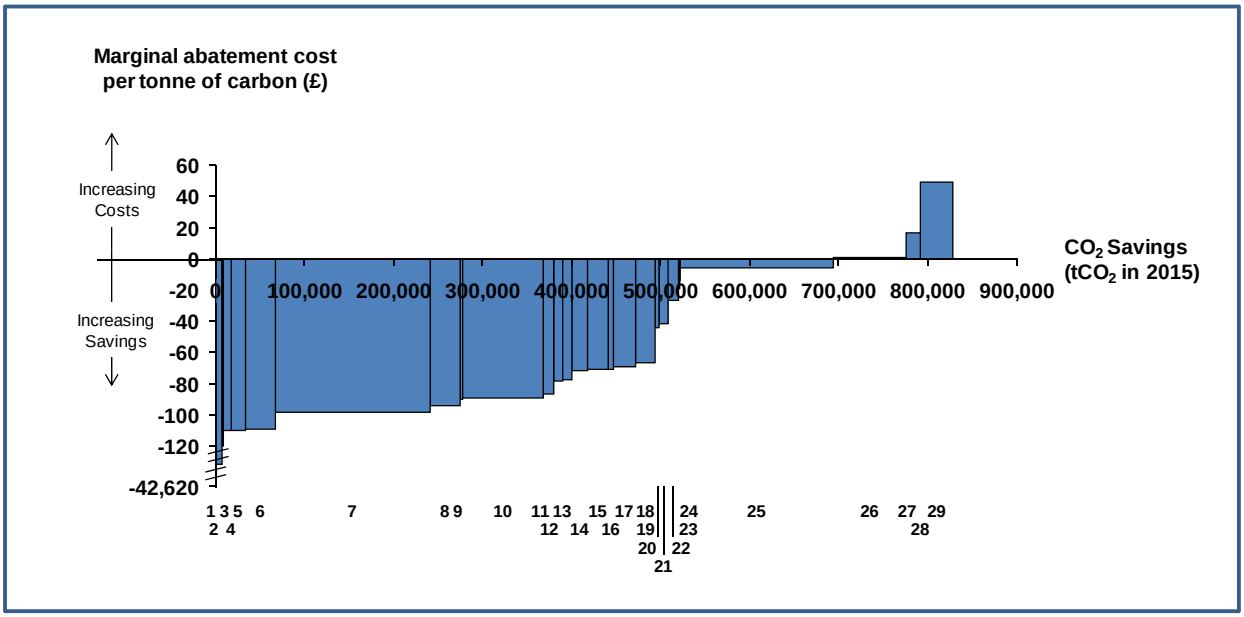
Option		£/tCO$_2$	CO$_2$ savings (tCO$_2$ in 2015)
1	Introduce hibernation system for stations	-120	1,255
2	Energy awareness campaign	-104	1,674
3	Upgrade garage and workshop heating	-60	214
4	Install high efficiency lighting and intelligent lighting controls	-45	3,745
5	Improve building insulation levels	-19	951
6	Boiler replacement/optimisation for HQ/control centres	-15	171
Total annual CO$_2$ savings in 2015 – all measures			8,009

The MAC Curve for the Ambulance Trusts category looks different to the others because we only have information for a relatively small number of measures, all of which are cost-effective. The most cost-effective option appears to be to introduce a hibernation system that shuts down all computer systems to save energy when not in use. The total savings of about 8 ktCO$_2$/yr represent about 15% of the baseline CO$_2$ emissions from buildings in this Trust category. Nearly half of these potential savings come from installing more efficient lighting systems.

3.1.1 A MAC Curve for NHS England

The buildings-related CO$_2$ reduction options considered for different categories of Trust were combined with CO$_2$ reduction options for transport and procurement to produce an overall MAC Curve for NHS England, as shown in Figure 7.

Figure 7 – NHS England MAC Curve



Option		£/tCO$_2$	CO$_2$ savings (tCO$_2$ in 2015)
1	Packaging	-42617	2
2	Teleconferencing	-2051	6,827
3	Introduce hibernation system for stations	-120	1,255
4	Improve the efficiency of chillers	-110	9,133
5	Voltage optimisation	-110	16,828
6	1 degree C	-110	32,763
7	CHP installation	-98	173,975
8	Improve lighting controls	-94	34,286
9	Variable speed drives	-90	3,083
10	Energy awareness campaign	-89	90,265
11	Building management system optimisation	-86	11,521
12	Improve insulation to pipe work, and/in boiler house	-79	10,264
13	Decentralisation of hot water boilers	-77	10,612
14	Improve heating controls	-72	17,219
15	Roof insulation	-71	22,869
16	Improve the efficiency of steam plant or hot water boiler plant	-71	6,367
17	Wall insulation	-70	24,624
18	Energy efficient lighting	-67	22,290
19	Upgrade garage and workshop heating	-60	214
20	Install high efficiency lighting and intelligent lighting controls	-45	3,745
21	Wind turbine	-42	10,722
22	Insulation - window glazing and draught proofing	-27	11,831
23	Improve building insulation levels (U-levels)	-19	951
24	Boiler replacement/optimisation for HQ/control centres	-15	171
25	Biomass boiler	-6	172,724
26	Travel planning	1	81,524
27	Office electrical equipment improvements	17	15,900
28	Solar hot water	49	0
29	Electric vehicles	49	36,969
Total annual CO$_2$ savings in 2015 – all measures			828,935

The total carbon savings from all measures are about 829 $ktCO_2$ /yr, including both the buildings measures listed in the Trust-level MACCs above and the NHS-wide transport and procurement measures. Of this, about 776 $ktCO_2$/yr can be achieved from measures that are cost-effective or approximately break even over their lifetime. Many of the more cost effective measures involve relatively low capital costs, such as, improved control systems or awareness raising campaigns. The largest savings would come from installing CHP systems in about half of the existing Acute Trusts that currently do not have CHP, and from introducing biomass boilers to 20% of the Trusts. Major savings are also possible from travel planning, energy awareness campaigns and improvements in lighting and heating controls. On the right of the Curve, solar water heating and electric vehicles appear to be the least cost-effective of the options assessed but may be suitable in certain applications and locations. The introduction of procedure packs used in operations (option 1) appears to be the most cost-effective but the carbon savings are very small. This is because there are large savings to be made in staff time and in landfill tax. It should be noted that the low level of carbon savings shown is a result of the limited scope of initial study findings. We understand that further work is underway to derive figures on potential savings across a wider range of surgical procedures. It is anticipated that this work will demonstrate more substantial carbon savings. We also considered a reduction in drugs wastage as a possible measure for reducing CO_2 and costs but the data are uncertain and so this measure has not been included in the above MAC Curve. The effect of including an indicative 5% reduction in drugs wastage is shown in the MAC Curve in Appendix 2.

Although key conclusions from the NHS England MACC in Figure 7 are the same as those from the earlier version included in the NHS carbon reduction strategy update, there are differences at a detailed level. This is because we have made certain changes as a result of considering useful comments that the Stakeholder Group have made on earlier versions of this report. For instance, we have revisited the CHP assumptions and reduced the cost-effectiveness and uptake rates for CHP; this has brought certain assumptions into line with a recent detailed report by BRE for the Department of Health, and AEA's very recent work for DECC on the potential for CHP in the UK[10]. Having reduced the CHP potential, we looked again at biomass as an alternative and introduced biomass boilers in some of the Large Acute and Small/Medium Acute Trusts without CHP. Data on other CO_2 reduction measures have also been re-analysed in response to the comments and suggestions, resulting in changes to the costs or carbon savings in places. Finally, we removed the drugs wastage measure from the MACC for the reason discussed above.

To some extent this demonstrates the many judgements that have to be made for this high-level type of MACC, and the value of the discussion they facilitate. As stated, the high-level messages remain unchanged. Specific Trusts or hospitals would be able to produce more definitive MACCs for their own circumstances, because it will be practicable to use local specific data and allow for implementation and operational realities.

It must be noted that some of the measures used in this analysis may have social benefits or costs associated with them. An example is the health benefits and reduced air pollution associated with the development of active travel plans. It is impossible to predict or quantify the effects of these benefits or costs and it is considered that many of the costs are lessened given appropriate communications and ancillary measures.

3.2 Scaling the results for your Trust

Approximate estimates of the costs and CO_2 savings can be achieved through scaling the results from this project. This could be used to identify abatement options which would merit further investigation. One of the aims of this project is to demonstrate the usefulness of MAC Curves. Trusts could compile organisation specific MAC Curves to gain a clear picture of the cost effectiveness of a range of CO_2 reductions relevant to specific circumstances.

To produce approximate estimates the first step is to decide which of the four categories of NHS Trust considered in this study is most similar to your Trust. The next step is to look up the average electricity usage in this category of NHS Trust in the table in Section 2.3.3. Having done that, divide the electricity use at your Trust (which can be accessed from the ERIC database if you do not have it -

[10] AEA report to DECC, Interaction between different incentive to support renewable energy and their effect on CHP, January 2010

http://www.hefs.ic.nhs.uk/ReportFilter.asp) by the average from Section 2.3.3. This gives you a multiplier that will allow you to scale the costs and CO_2 savings for individual options in Appendix 3. To do this simply multiply the appropriate cost or CO_2 savings by the multiplier.

To gain a range of values you could repeat the process for gas consumption. However, it is important to note that the figures generated using this crude approach are estimates. They should be treated as very approximate estimates and be used to guide further audit and feasibility studies.

Appendices

Appendix 1: CO_2 reduction options

Appendix 2: Worked examples of methodology

Appendix 3: Detailed costs and CO_2 savings

Appendix 1

CO_2 reduction options

This appendix provides tabular data on the CO_2 reduction measures that have been included in each of the MAC Curves for different Trust categories and at the NHS level. The main data sources were:

Capital costs (£): For the energy efficiency options (e.g. energy efficient lighting, insulation), data on capital costs were obtained primarily from the NHS Carbon Management Plans (CMPs). Other sources included the BRE report for the NHS[11], and information sent to the project team from Salix[12] and the Carbon Trust. For low carbon options (i.e. biomass boiler, CHP, solar hot water and wind turbine), data were based on a range of publicly available information, information that the project team holds from past involvement in related projects and the experience of the team members.

Changes in operating costs (£): For the energy efficient options, changes in operating costs represent financial savings (or costs) that occur from the implementation of the measure. This takes account of fuel savings and any other changes in operating costs. Data were obtained primarily from the NHS CMPs, cross-checked and supplemented by information from the BRE report for the NHS, and information sent to the project team from Salix and the Carbon Trust. For low carbon options, the project team constructed a simple low carbon technology appraisal model covering capital costs, operating costs, plant availability etc. for typically-sized units applicable to different Trust categories. Data imported to this model were based on a range of publicly available information, information that the project team holds from their past involvement in related projects and the experience of the team members.

Any costs or benefits associated with emissions trading (either the EU ETS or CRC Energy Efficiency Schemes) have not been accounted for as they are unpredictable and will vary by Trust.

Payback times (£): Payback times were calculated on the basis of initial capital cost and ongoing operating cost without discounting.

Carbon savings - % reduction in carbon baseline: For the energy efficiency options, data on carbon savings were obtained primarily from the NHS CMPs, supported by data from the report by BRE for the NHS and information sent to the project team from Salix and the Carbon Trust. Carbon savings were then expressed as a percentage of baseline CO_2 emissions[13] for a particular type of Trust. For low carbon options, the project team used the low carbon technology appraisal model discussed above to estimate the annual carbon savings associated with a typical installation. Carbon savings were then expressed as a percentage of baseline CO_2 emissions for a particular type of Trust.

Uptake rates: Uptake rates represent the potential opportunity that each option has, for being implemented in a particular Trust type, taking into account the current uptake rate where this is known or where it can be estimated. Uptake rates were informed by analysing the frequency at which the options appear in the NHS Carbon Management Plans, information from the ERIC database, sources that the project team holds and the team's past experience.

Further details of the methodology and assumptions are provided in Appendix 2.

[11] BRE, Identifying Minimum Carbon Emission Scenarios for the NHS Estate, 20 March 2009
[12] http://www.salixfinance.co.uk/thecompany.html
[13] Baseline CO_2 emissions derived from the ERIC database

Table A1: Carbon abatement options for Large Acute Trusts

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Energy efficient lighting	Use of energy saving lighting technology (e.g. high frequency lighting, LED lighting, low energy lighting)	£150,000	£46,897	7	3.2	0%	2%	50%
Improve lighting controls	Use of lighting controls to reduce lighting in areas that do not need to be fully lit at all times (e.g. passive infrared sensors, photoelectric/ dimming controls, zonal switching)	£180,000	£70,345	22	2.6	0%	3%	60%
Energy awareness campaign	Energy awareness campaigns that target areas of energy wastage (e.g. encourage switch off lighting and equipment when not in use)	£30,000	£106,132	3	0.3	3%	3%	65%
1 degree C	Review heating set points and reduce by 1 degree Celsius wherever possible.	No cost	£88,813	3	0.0	5%	0%	40%
Improve the efficiency of steam plant or hot water boiler plant	Opportunities to improve boiler efficiency for district heating systems (e.g. boiler or burner replacement, heat recovery systems like stack economisers, flash steam or condensate recovery, improving controls like applying TDS blowdown on steam boilers.	£200,000	£56,288	17	3.6	3%	0%	40%
Biomass boiler	Installation of biomass boiler as an alternative fuel source to non-renewable fossil fuels.	£2,400,000	£233,127	17	10.3	52%	0%	20%

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Improve the efficiency of chillers	Implementation of measures that will operate a chiller at peak performance can save energy as well as maintenance costs (e.g. keeping condenser and evaporator tubes clean, pre-treating condensing water, fitting variable speed drives to chiller motors, modernising chiller control systems and possibly even replacing older plant)	£75,000	£82,069	22	0.9	0%	4%	25%
Building management system optimisation	Installation of a computer-based control system that allows energy-using services to be centrally managed, notably heating, ventilation and air conditioning (HVAC) and sometimes lighting.	£200,000	£65,659	22	3.0	1%	2%	15%
Improve heating controls	Improving a building or site's heating controls (e.g. fitting of thermostatic radiator valves (TRVs) to radiators, installing PIR occupancy sensors and other automatic timing controls, and upgrading room thermostats).	£100,000	£42,216	22	2.4	2%	0%	40%
Roof insulation	Replacing or installing insulation to loft or roof spaces, based on the U-values determined by the 2006 Building Regulations.	£200,000	£101,318	22	2.0	5%	0%	20%
Wall insulation	Replacing or installing insulation to external walls, based on the U-values determined by the 2006 Building Regulations.	£300,000	£112,575	22	2.7	6%	0%	20%

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Insulation - window glazing and draught proofing	Improving the U-value of external windows by replacement and implementing draught proofing measures, based on the U-values determined by the 2006 Building Regulations.	£500,000	£56,288	22	8.9	3%	0%	20%
Improve Insulation to pipe work, and/in boiler house	Insulating pipe work to the standards set out in BS 5422 (2001) on both heated and cooled pipe work and surfaces (including valves, flanges etc).	£100,000	£56,288	22	1.8	3%	0%	20%
Variable speed drives	Installation of VSDs to fan and pump motors.	£75,000	£23,448	10	3.2	0%	1%	25%
Voltage optimisation	Voltage optimisation (also known as 'voltage correction') to eliminate the discrepancy between supply voltage and the optimum voltage needed by electrical equipment and reduce energy losses.	£75,000	£93,793	22	0.8	0%	4%	30%
CHP	Installation of a Combined heat and power (CHP) system that simultaneously generates usable heat and power (usually electricity) through a single process.	£2,780,189	£989,095	10	2.8	-35%	68%	53%*
Solar Hot Water	Installation of a 300 kW Solar Hot Water system.	£300,000	£11,209	25	26.8	0.7%	0%	28%
Wind turbine	Installation of an 80 kW stand alone wind turbine.	£310,000	£36,228	25	8.6	0%	1.6%	53%

*As a percentage of Trusts currently without CHP

Table A2: Carbon abatement options for Small/Medium Acute Trusts

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Energy efficient lighting	Use of energy saving lighting technology (e.g. high frequency lighting, LED lighting, low energy lighting).	£50,000	£18,399	7	2.7	0%	2%	50%
Improve lighting controls	Use of lighting controls to reduce lighting in areas that do not need to be fully lit at all times (e.g. passive infrared sensors, photoelectric/dimming controls, zonal switching).	£85,000	£27,599	22	3.1	0%	3%	55%
Energy awareness campaign	Energy awareness campaigns that target areas of energy wastage (e.g. encourage switch off lighting and equipment when not in use).	£18,500	£34,220	3	0.5	3%	3%	75%
1 degree C	Review heating set points and reduce by 1 degree celsius wherever possible.	£0	£26,035	3	0.0	5%	0%	40%
Improve the efficiency of steam plant or hot water boiler plant	Opportunities to improve boiler efficiency for district heating systems (e.g. boiler or burner replacement, heat recovery systems like stack economisers, flash steam or condensate recovery, improving controls like applying TDS blowdown on steam boilers.	£80,000	£18,621	17	4.3	3%	0%	25%
Biomass boiler	Installation of biomass boiler as an alternative fuel source to non-renewable fossil fuels.	£810,000	£78,680	17	10.3	53%	0%	20%

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Improve the efficiency of chillers	Implementation of measures that will operate a chiller at peak performance can save energy as well as maintenance costs (e.g. keeping condenser and evaporator tubes clean, pre-treating condensing water, fitting variable speed drives to chiller motors, modernising chiller control systems and possibly even replacing older plant)	£25,000	£13,799	22	1.8	0%	2%	15%
Building Management System optimisation	Installation of a computer-based control system that allows energy-using services to be centrally managed, notably heating, ventilation and air conditioning (HVAC) and sometimes lighting.	£150,000	£49,212	22	3.0	2%	4%	15%
Improve heating controls	Improving a building or site's heating controls (e.g. fitting of thermostatic radiator valves (TRVs) to radiators, installing PIR occupancy sensors and other automatic timing controls, and upgrading room thermostats).	£50,000	£18,621	22	2.7	3%	0%	30%
Roof insulation	Replacing or installing insulation to loft or roof spaces, based on the U-values determined by the 2006 Building Regulations.	£120,000	£37,242	22	3.2	6%	0%	20%
Wall insulation	Replacing or installing insulation to external walls, based on the U-values determined by the 2006 Building Regulations.	£140,000	£37,242	22	3.8	6%	0%	20%

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Insulation - window glazing and draught proofing	Improving the U-value of external windows by replacement and implementing draught proofing measures, based on the U-values determined by the 2006 Building Regulations.	£150,000	£15,518	22	9.7	3%	0%	20%
Improve Insulation to pipe work, and/in boiler house	Insulating pipe work to the standards set out in BS 5422 (2001) on both heated and cooled pipe work and surfaces (including valves, flanges etc).	£40,000	£18,621	22	2.1	3%	0%	20%
Variable speed drives	Installation of VSDs to fan and pump motors.	£25,000	£9,200	10	2.7	0%	1%	15%
Voltage optimisation	Voltage optimisation (also known as 'voltage correction') to eliminate the discrepancy between supply voltage and the optimum voltage needed by electrical equipment and reduce energy losses.	£50,000	£36,798	22	1.4	0%	4%	20%
CHP installation	Installation of a Combined heat and power (CHP) system that simultaneously generates usable heat and power (usually electricity) through a single process.	£1,028,528	£365,914	10	2.8	-36%	68%	53%*
Solar hot water	Installation of a 500 kW Solar Hot Water system.	£180,000	£6,725	25	26.8	1.2%	0%	28%
Wind turbine	Installation of a 250 kW stand alone wind turbine.	£135,000	£9,434	25	14.3	0%	1.0%	53%

*As a percentage of Trusts currently without CHP

Table A3: Carbon abatement options for Non-Acute and PCT Trusts

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Energy efficient lighting	Use of energy saving lighting technology (e.g. high frequency lighting, LED lighting, low energy lighting)	£40,000	£9,699	7	4.1	0%	3%	65%
Improve lighting controls	Use of lighting controls to reduce lighting in areas that do not need to be fully lit at all times (e.g. passive infrared sensors, photoelectric/dimming controls, zonal switching)	£40,000	£9,699	22	4.1	0%	3%	75%
Energy Awareness Campaign	Energy awareness campaigns that target areas of energy wastage (e.g. encourage switch off lighting and equipment when not in use)	£9,000	£16,879	3	0.5	4%	6%	80%
1 degree C	Review heating set points and reduce by 1 degree celsius wherever possible.	£0	£8,851	3	0.0	5%	0%	40%
Improve the efficiency of steam plant or hot water boiler plant	Opportunities to improve boiler efficiency for district heating systems (e.g. boiler or burner replacement, heat recovery systems like stack economisers, flash steam or condensate recovery, improving controls like applying TDS blowdown on steam boilers.	£130,000	£35,554	17	3.7	15%	0%	15%

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Biomass Boiler	Installation of biomass boiler as an alternative fuel source to non-renewable fossil fuels.	£200,000	£31,141	17	6.4	51%	0%	20%
Decentralisation of hot water boilers	Replacement of large, centralised boiler plant (typically steam) with a number of smaller, more efficient localised condensing boilers.	£100,000	£35,554	13	2.8	15%	0%	25%
Office electrical equipment improvements	Measures to reduce the impact of IT and office equipment (e.g. Enable energy saving features, purchase equipment with the Energy Star logo).	£100,000	£32,330	3	3.1	0%	10%	40%
Building Management System optimisation	Installation of a computer-based control system that allows energy-using services to be centrally managed, notably heating, ventilation and air conditioning (HVAC) and sometimes lighting.	£50,000	£13,255	22	3.8	2%	3%	20%
Improve Heating controls	Improving a building or site's heating controls (e.g. fitting of thermostatic radiator valves (TRVs) to radiators, installing PIR occupancy sensors and other automatic timing controls, and upgrading room thermostats).	£50,000	£9,481	22	5.3	4%	0%	40%
Roof insulation	Replacing or installing insulation to loft or roof spaces, based on the U-values determined by the 2006 Building Regulations.	£75,000	£13,037	22	5.8	6%	0%	35%

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Wall insulation	Replacing or installing insulation to external walls, based on the U-values determined by the 2006 Building Regulations.	£75,000	£14,222	22	5.3	6%	0%	35%
Insulation - window glazing and draught proofing	Improving the U-value of external windows by replacement and implementing draught proofing measures, based on the U-values determined by the 2006 Building Regulations.	£100,000	£7,111	22	14.1	3%	0%	35%
Improve Insulation to pipe work, and/in boiler house	Insulating pipe work to the standards set out in BS 5422 (2001) on both heated and cooled pipe work and surfaces (including valves, flanges etc).	£18,000	£4,741	22	3.8	2%	0%	25%
Voltage optimisation	Voltage optimisation (also known as 'voltage correction') to eliminate the discrepancy between supply voltage and the optimum voltage needed by electrical equipment and reduce energy losses.	£25,000	£12,932	22	1.9	0%	4%	10%
Solar Hot Water	Installation of a 150 kW Solar Hot Water system.	£90,000	£3,363	25	26.8	1.6%	0%	28%
Wind turbine	Installation of a 10 kW stand alone wind turbine.	£25,000	£380	22	65.8	0%	0.1%	1%

Table A4: Carbon abatement options for Ambulance Trusts

Name of measure	Description	Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Improve building insulation levels	Replacing or improving insulation to loft or roof spaces, external walls based on the U-values determined by the 2006 Building Regulations.	£60,000	£8,750	22	6.9	10.0%	0.0%	50%
Install high efficiency lighting and intelligent lighting controls	Use of energy saving lighting technology (e.g. high frequency lighting, LED lighting, low energy lighting) and of lighting controls to reduce lighting in areas that do not need to be fully lit at all times (e.g. passive infrared sensors, photoelectric/dimming controls, zonal switching)	£18,650	£26,250	7	0.7	0.0%	15.0%	75%
Upgrade garage and workshop heating	Make improvements to the heating of the garages and workshops used for the ambulances.	£20,000	£4,700	22	4.3	2.3%	0.0%	50%
Boiler replacement/optimisation for HQ/control centres	Boiler replacement and/or measures to improve boiler efficiency at head quarters and control centres.	£3,000	£750	22	4.0	1.5%	0.0%	60%
Introduce hibernation system for stations	Hibernation systems shut down all computer systems to save energy when not in use.	£16,000	£23,750	15	0.7	3.0%	3.0%	80%
Energy Awareness Campaign	Energy awareness campaigns that target areas of energy wastage (e.g. encourage switch off lighting and equipment when not in use)	£9,000	£24,000	4	0.4	4.0%	4.0%	80%

Table A5: Additional carbon abatement options applied to whole NHS

Name of measure	Description	Whole NHS Trust						
		Capital costs (£)	Savings in annual operating costs (£/yr)	Lifetime (years)	Payback times (years)	% Reduction in Carbon Baseline (Fossil fuels)	% Reduction in Carbon Baseline (Electricity)	Uptake rates (%)
Travel Planning	Green travel plan and/or improvements to the transport services (e.g. car sharing, cycle to work schemes, increase public transport, low emissions vehicles)	£425,000	-£37,900	10	N/A	34.5%	5.8%	80%
Electric Vehicles	Conventional diesel or petrol vehicles used within the hospital fleets to be replaced with electric vehicles and used for all journeys under 25 miles.	£161,761,082	£6,016,949	12	26.9	57.0%	0.0%	50%
Teleconferencing	Encourage the use of teleconferencing to reduce business mileage.	£4,301,000	£8,367,440	7	0.5	5.0%	0.0%	100%
Packaging	The introduction of procedure packs used in operations. The packs include a range of surgical consumables including table drapes, beakers, swabs, and a limited range of surgical instruments used for specific surgical operations, as an alternative to each instrument being individually packaged.	£692,035	£375,570	5	1.8	N/A	N/A	35%

Appendix 2

Methodology and Assumptions

This Appendix explains our methodology and assumptions in more detail. It comprises:

- A step-by-step worked example for calculating the costs and emissions savings associated with introducing more efficient lighting in Small/Medium Acute Trusts.
- A explanation of how interactions and overlaps were dealt with in calculating the costs and carbon savings.
- Details of the assumptions and data sources used in deriving data for:
    - Energy efficiency measures
    - Renewables measures
    - CHP
    - Transport measures
    - Procurement measures
- The impact on the MACC of including an indicative measure on reducing drugs wastage

Worked Example – Efficient Lighting in Small/Medium Trusts

Baseline CO2	CO2 baseline in 2015 for all small/medium Trusts - fossil (tCO2/yr) =	480,710		Input value from buildings baseline worksheet
	CO2 baseline in 2015 for all small/medium Trusts - electricity (tCO2/yr) =	552,137		Input value from buildings baseline worksheet
	Total number of small/medium Trusts	103		Sum of numbers of small/medium Trusts listed in buildings baseline worksheet
	CO2 baseline in 2015 for single small/medium Trust - fossil (tCO2/yr) =	4,667		Calculated - CO2 baseline for all Trusts divided by number of Trusts
	CO2 baseline in 2015 for single small/medium Trust - electricity (tCO2/yr) =	5,361		Calculated - CO2 baseline for all Trusts divided by number of Trusts
% CO2 savings	CO2 savings as %age of fossil energy baseline at 100% uptake =	0%		Input value from carbon savings worksheet
	CO2 savings as %age of electricity baseline at 100% uptake =	2%		Input value from carbon savings worksheet
	CO2 savings per year in 2015 for single Trust if 100% uptake - fossil (tCO2/yr) =	0		Calculated - %age CO2 savings at 100% uptake x CO2 baseline for single Trust
	CO2 savings per year in 2015 for single Trust if 100% uptake - electricity (tCO2/yr) =	107		Calculated - %age CO2 savings at 100% uptake x CO2 baseline for single Trust
	CO2 savings per year in 2015 for single Trust if 100% uptake - total (tCO2/yr) =	107		Calculated - sum of fossil and electricity savings
	CO2 savings per year in 2015 for all S/M Trusts if 100% uptake - fossil (tCO2/yr) =	0		Calculated - CO2 savings at 100% uptake x max realistic uptake rate
	CO2 savings per year in 2015 for all S/M Trusts if 100% uptake - electricity (tCO2/yr) =	11043		Calculated - CO2 savings at 100% uptake x max realistic uptake rate
	CO2 savings per year in 2015 for all S/M Trusts if 100% uptake - total (tCO2/yr) =	11043		Calculated - sum of fossil and electricity savings
Measure uptake	Maximum realistic uptake of measure in 2015 =	50%		Input value from uptake of measures worksheet
CO2 savings/yr	CO2 savings per year in 2015 for single Trust if max uptake - fossil (tCO2/yr) =	0		Calculated - CO2 savings at 100% uptake x max realistic uptake rate
	CO2 savings per year in 2015 for single Trust if max uptake - electricity (tCO2/yr) =	54		Calculated - CO2 savings at 100% uptake x max realistic uptake rate
	CO2 savings per year in 2015 for single Trust if max uptake - total (tCO2/yr) =	54		Calculated - sum of fossil and electricity savings
	CO2 savings per year in 2015 for all S/M Trusts if max uptake - fossil (tCO2/yr) =	0		Calculated - CO2 savings at 100% uptake x max realistic uptake rate
	CO2 savings per year in 2015 for all S/M Trusts if max uptake - electricity (tCO2/yr) =	5521		Calculated - CO2 savings at 100% uptake x max realistic uptake rate
	CO2 savings per year in 2015 for all S/M Trusts if max uptake - total (tCO2/yr) =	5521		Calculated - sum of fossil and electricity savings
Measure lifetime	Lifetime of measure (years) =	7		Input value from desc and life of measures worksheet
Lifetime CO2	Lifetime CO2 savings for single Trust if max uptake - fossil (tCO2/yr) =	0		Calculated - annual CO2 savings x lifetime
	Lifetime CO2 savings for single Trust if max uptake - electricity (tCO2/yr) =	375		Calculated - annual CO2 savings x lifetime
	Lifetime CO2 savings for single Trust if max uptake - total (tCO2/yr) =	375		Calculated - sum of fossil and electricity savings
	Lifetime CO2 savings for all S/M Trusts if max uptake - fossil (tCO2/yr) =	0		Calculated - annual CO2 savings x lifetime
	Lifetime CO2 savings for all S/M Trusts if max uptake - electricity (tCO2/yr) =	38650		Calculated - annual CO2 savings x lifetime
	Lifetime CO2 savings for all S/M Trusts if max uptake - total (tCO2/yr) =	38650		Calculated - sum of fossil and electricity savings

Worked Example – Efficient Lighting in Small/Medium Trusts (continued)

Capital costs	Capital cost for any single S/M Trust implementing the measure (£) =	50000		Input value from NPV Cap Costs worksheet
	Annualised capital cost for any single S/M Trust implementing the measure (£) =	7143		Calculated - capital cost / lifetime
	Capital costs for all S/M Trusts if 100% uptake (£) =	5150000		Calculated - cost per Trust x number of Trusts
	Capital costs for all S/M Trusts if max uptake (£) =	2575000		Calculated - cost at 100% uptake x uptake rate
	Discount rate for NPV calculations (%) =	3.5%		Input value from discount rates and carbon price worksheet
Operating costs	Operating costs per year (excl fuel savings) for single S/M Trust implementing measure (£/yr) =	0		Input value from operating costs worksheet (cost 1 + cost 2)
	NPV of operating costs (excl fuel savings) for single Trust at 100% uptake =	0		Calculated using discounted cash flows
	NPV of operating costs (excl fuel savings) for single Trust at max uptake =	0		Calculated - costs x uptake rate
	NPV of operating costs (excl fuel savings) for all S/M Trusts at 100% uptake =	0		Calculated - cost for one Trust x no of Trusts
	NPV of operating costs (excl fuel savings) for all S/M Trusts at max uptake =	0		Calculated - costs x uptake rate
Fuel savings	Fuel cost savings per year for single S/M Trust implementing measure (£/yr) =	-18399		Input value from operating costs worksheet (cost 4 + cost 5)
	NPV of fuel cost savings for single Trust at 100% uptake =	-112503		Calculated using discounted cash flows
	NPV of fuel cost savings for all S/M Trusts at 100% uptake =	-11587765		Calculated - cost for one Trust x no of Trusts
	NPV of fuel savings for all S/M Trusts at max uptake =	-5793882		Calculated - costs x uptake rate
Total costs	Net NPV costs for single Trust at 100% uptake (£) =	-62503		Calculated - capital + operating + fuel
	Net NPV costs for single Trust at max uptake (£) =	-31251		Calculated - cost x uptake rate
	Net NPV costs for all S/M Trusts at 100% uptake (£) =	-6437765		Calculated - cost for one Trust x no of Trusts
	Net NPV costs for all S/M Trusts at max uptake (£) =	-3218882		Calculated - cost for one Trust x no of Trusts
Data for MACC	£/tCO2 based on NPV costs and lifetime CO2 savings =	-83		Calculated - net NPV at max uptake / lifetime CO2 at max uptake
	tCO2 savings in 2015 (without interactions) =	5521		From above

Dealing with Interactions and Overlaps

In estimating the carbon savings potential it is important to take account of interactions and overlaps between measures. Interactions concern situations where the carbon savings from a measure are reduced because another measure has been installed previously. For example, savings from more efficient boilers are lower if the building insulation is improved first. Overlaps concern measures that can't be introduced because another (more cost-effective option) has already been adopted. For example, if a gas-fired combined heat and power (CHP) system has been installed then it wouldn't be cost-effective to introduce solar water heating subsequently.

For space heating and insulation measures we have taken the following approach to interactions:

- All insulation measures are assumed to be taken up first, which reduces the carbon savings from space heating measures introduced subsequently.
- Space heating carbon savings are reduced by an interaction factor derived from the relative energy performance of a well insulated and average building. For large Trusts this factor has been estimated at 0.90 while for other Trust types it is 0.95, based on data from past audits of NHS buildings.
- A proportion of carbon savings from measures such as energy awareness campaigns are also reduced using this interaction factor, as only some of the carbon savings are associated with space heating.

There is also an interaction in the transport area, whereby additional use of teleconferencing reduces the demand for business travel by 5%, which reduces the impact of the subsequent introduction of electric vehicles proportionally.

The only significant overlaps are in the area of building heating options. Here we have assumed that the most cost-effective option (usually CHP) is taken up first to its maximum potential, followed by the next most cost-effective and so on. For acute Trusts (small/medium and large) this has produced a scenario whereby half of the Trusts that don't currently have CHP install it. Biomass boilers are then assumed to be taken up by the remaining Trusts, up to the maximum uptake rate for biomass boilers. Note this is a different approach than was taken earlier in the study, when the remaining 50% were assumed to improve their existing gas boilers instead.

Assumptions and Data Sources – Energy Efficiency Measures

Data sources used to generate estimates of potential technology group costs and savings included over 30 Carbon Trust NHS Carbon Management Plans and a summary of the measures funded in the Public Sector by Salix Finance. Each Carbon Management plan contained multiple measures, providing us with almost 200 individual fully costed projects, providing over 1000 individual data points. The Salix finance data set represents an aggregation of over 2500 individual projects across 27 distinct technology groupings.

The data points contained within these data sets were normalized (in terms of units and assumed energy prices) to generate an average expected financial saving for each measure. In addition outliers were discarded and the remaining data set focused on data from projects that were considered to represent a fuller application of the measure (e.g. energy efficient lighting through a whole hospital rather than just in one corridor). Capital costs reported in the projects were scaled by Trust size to ensure that differences in the size of sponsoring Trust's were standardized.

This standardized data set was then applied to the total energy consumption of each NHS Trust category to generate an estimate of the total potential for emissions reduction projects across the NHS as a whole. This formed the final data set used to calculate the lifetime costs and benefits for the compilation of the MAC Curve.

Assumptions and Data Sources – Renewables

The performance and cost-effectiveness of wind turbines and solar hot water is highly dependent on the size of the unit and the installation site, e.g. wind speed, latitude, roof angle. We used high level

assumptions regarding the size of installation (kW) with a scale down factor based on different Trusts sizes. Costs, CO_2 savings and payback times were calculated on the basis of those specific sizes and should by no means treated as fully representative of that specific Trust type. Depending on the nature of the site of installation (e.g. urban/suburban/rural, available roof area), sizes of any kind could be installed in a specific Trust type that could result in higher CO_2 savings and lower payback times.

Data on biomass boilers, wind and solar water heating (SWH) was developed using a bottom-up approach by AEA experts in these technologies. They drew on their own expertise and on a range of literature sources, including an unpublished report by BRE "Identifying Minimum Carbon Emission Scenarios for the NHS Estate".

Biomass Boilers
The assumed sizes of biomass boilers were: 4,000 kW for Large Acutes; 1,350 kW for Small/Medium Acutes and 500 kW for Non-Acutes/PCTs. This translated to a saving in site gas consumption of about 50-55% in each case. Fuel costs were assumed to be 2.2p/kWh. The efficiency of the biomass boiler was assumed to be 85%, replacing a conventional gas boiler with an efficiency of 75%. Load factor was taken to be 90%. An uptake rate of 20% was then applied to take account of the fact that not all sites are suitable for biomass boilers. For example, rural and suburban locations are more likely to be suitable than city centre locations. There are also site-specific factors.

Wind Turbines
The assumed sizes of wind turbines were: 250 kW for Large Acutes; 80 kW for Small/Medium Acutes and 10 kW for Non-Acutes/PCTs. The efficiency was taken to be 70%. The load factor varied by turbine size: 25% for the 250 kW unit, 20% for the 80 kW unit and 8% for the 10 kW unit. Uptake rates for the 250 kW and 80 kW units were based on information on the unpublished BRE report. This report distinguished the potential for 250 kW turbines in rural areas and 80 kW turbines in suburban areas, rather than splitting it by Trust category. Therefore there is not a direct correlation but the total wind capacity is in line.

Solar Water Heating
The assumed sizes of SWH systems were: 500 kW for Large Acutes; 300 kW for Small/Medium Acutes and 150 kW for Non-Acutes/PCTs. The efficiency was taken to be 80% and the load factor 10%. Uptake rates were based on the maximum roof area available to meet half the domestic hot water load of a Trust, from the unpublished BRE report.

Assumptions and Data Sources – CHP

The annual electrical demand of an average Trust currently without CHP was calculated to be 27,674 MWh/Yr for a Large Trust and 9,482 MWh/Yr for a Small/Medium Trust using ERIC data. The equivalent annual fuel demand was 56,698 MWh/Yr for a Large Trust and 20,975 MWh/Yr for a Small/Medium Trust. The CHP unit was assumed to replace a conventional boiler with an efficiency of 75% running on 100% natural gas. Each CHP unit was sized on a thermal capacity 70% of average heat demand based on experience. The CHP electrical efficiency was assumed to be 36%, with thermal efficiency of 44% (based on gross calorific fuel input). There was assumed to be a heating demand 8760 hours per year, with CHP available for 90% of this. Existing boilers were assumed to be 75% efficient natural gas provide back up and top up heat. The installed CHP cost was taken as £1,000/kWe (2009 real terms), which excludes costs for overcoming site specific barriers such as lack of plantroom space, pipework connecting buildings etc. Annual CHP maintenance costs were taken at £10/MWh (2009 real terms). No displacement of boiler replacement or maintenance costs was assumed as the boiler is still needed for top up.

Assumptions and Data Sources – Transport Measures

Patient and Visitor Travel
The distance travelled by patient and visitor travel was provided by Kate Scott. Percentages were applied to these figures to work out the proportion of miles travelling to and from the NHS; the percentages used were taken from the SEI/-Arup report on the Carbon Footprint of the NHS in 2009.

The original data was expressed in the distance travelled per person per year (miles), but this did not detail which modes of transport were used for these distances. It was therefore necessary to determine the miles travelled by each mode. A percentage modal split was required in order to apply accurate emission factors to the distances travelled by miles.

The split was using data available in the National Travel Survey 2009. The survey states the number of miles travelled by each mode of transport in 2008. This data was normalised to provide the modal split in 2008; the percentages were then applied to the transport data for the NHS. The modal split was assumed to be constant in the projections of the future transport emissions baseline.

This modal split enabled the baseline emissions of NHS travel to be calculated by applying the appropriate emission factors to each mode of transport. The emission factors were taken from the Defra Company Reporting Guidelines 2009.

The resultant per person per annum emissions were then scaled up to the national level, by multiplying the travel emissions by the population of England in 2006, according to the Office for National Statistics.

Removal of GP travel data

It was also necessary to remove the GP travel data from the patient travel figures. GP travel information was obtained from a presentation by Steve Feast, Senior Advisor Health and Wellbeing, at Norfolk Primary Care Trust. This presentation provided the average distance travelled by patients to reach GPs, acute trusts and specialist centres. The distance travelled to GPs was doubled to account for the distance of a round trip.

The annual total distance travelled to GP practices was calculated by multiplying this distance by the estimated number of journeys to GPs in 2008-2009. This figure was taken from 'Trends in Consultation Rates in General Practice 1995/1996 to 2008/2009: Analysis of the QResearch® database'.
(http://www.ic.nhs.uk/webfiles/publications/gp/Trends_in_Consultation_Rates_in_General_Practice_1995_96_to_2008_09.pdf)

Staff Commuting

The total distance travelled to commute to the NHS was calculated by taking the average commuter distance in the UK, taken from the RAC Foundation (http://www.racfoundation.org/index.php?option=com_content&task=view&id=458&Itemid=35) and multiplying by the number of NHS employees (source: NHS website (http://www.nhsbreakingthrough.co.uk/About-the-NHS/NHS-and-the-environment.aspx).

The same modal split and emission factors used for patient and visitor travel were then applied to the data to calculate the baseline carbon emission for 2008/2009.

Staff Business Travel

Business travel miles were provided by the Department of Health. The mileage data had been gathered from the 1st November until 15th December 2009 - this was multiplied up to a full working year to achieve the baseline business mileage for 2008/2009.

Projection to 2015

Using data provided in the SEI/Arup report, linear interpolation was adopted to obtain the annual percentage change in patient, visitor and staff commuter travel. This percentage change was then used to calculate the emissions baseline for 2015. It was assumed that the modal split of this travel would remain constant.

For staff business travel, it was assumed that the total annual distance would remain constant, therefore the 2015 baseline was no different to that of the 2008/2009 baseline.

Teleconferencing

The total business mileage for the whole of the NHS was provided by the Department of Health. An assumption was made that teleconferencing could reduce this mileage by 5%. Consequently, the reduction in operating costs was the equivalent of 5% of the business mileage multiplied by 40p per

mile. In addition, the annual carbon savings were determined by applying a 5% reduction to the current carbon emissions of business mileage.

The capital costs associated with this option were calculated on the assumption that each Trust would need to buy 1 video conferencing suite.

Electrification of Fleet Vehicles
It was estimated that business mileage could be reduced by 16% through the implementation of this option. This percentage was based on two key sources of data:

- The case study of North Lincs and Goole NHS Trust. The case study provided us with the percentage of business mileage currently undertaken by pool or lease vehicles.
- The National Travel Survey 2009. An assumption was made that all journeys of 25 miles or less could be replaced by electric vehicles. Using data from this survey, it was possible to calculate the percentage of miles that were travelled on journeys of 25 miles or less.

The capital costs for this option were the upfront cost of purchasing electric vehicles. This cost was based on the marginal capital cost of purchasing an electric vehicle, multiplied by the number required by the NHS.

The operating cost savings were based on the marginal capital cost of purchasing an EV, taking into consideration the comparative prices of 1 MJ of electricity and 1 MJ of diesel, and the comparative MJ/km for both a diesel and electric vehicle.

The carbon savings were calculated by comparing the carbon intensity of motive energy in petrol, diesel and electric vehicles, as found in 'WWF study - The end of the oil age[14]'.

Travel Planning
The original data used for this option was provided by Addenbrookes Hospital, Cambridge. This data illustrated how the number of person trips has changed over time.

The carbon saving figure for this option was based on the Addenbrookes sample, and was obtained by creating a weighted average emission factor for 1993 and 2008. This factor calculated the average kg CO_2 per km travelled for each year; a comparison of the two factors calculated the percentage carbon saving of this option.

The capital costs associated with this option were accumulated from the cost of a new bus station and additional bike shed and changing facilities. It was assumed that there would also be an annual operating cost, to cover the additional cost of an annual 'Departure charge' for a new park and ride service, and a 'Bus ticket salary sacrifice scheme'. The costs from the Addenbrookes Hospital case study were then scaled up and applied to the NHS level.

Assumptions and Data Sources – Introduction of Procedure Packs in Operations

Data on the total number of operations in the NHS in 2008/2009 by type were used. Only one specific type of operation was considered for the introduction of procedure packs – the Anterior Cruciate Ligament (ACL) procedure. Supplementary data from the Department of Health (DH) showed that 16,444 ACL operations were carried out in 2008/09 and it was assumed that the same number would be carried out in 2015.

The procedure pack carbon savings were calculated based on initial data collected as part of a study being led by the DH. The study provided information on the total kg of CO_2 incorporated in both the current packaging and in the new procedure packs for ACL operations. The annual carbon savings were then reached by multiplying the savings made per unit by the number of these operations.

The capital costs associated with the introduction of procedure packs were mostly due to the additional staff cost required to implement the new procurement system.

[14] http://assets.panda.org/downloads/plugged_in_full_report___final.pdf

Similarly, savings in operating costs were found in the reduction of staff time. These savings would be made by theatre nurses and clinical staff during the operations, and also through the reduced amount of time spent in supplier negotiations, procurement administration and stock take. Further operating cost savings were identified in the avoided cost of waste management, due to the reduced waste produced by new procedure packs. The initial data provided stated the amount of waste saved per procedure pack, and this was multiplied by the number of operations to calculate the total amount of waste avoided through the procedure packs. Using the projected cost of landfill tax to 2015, the annual operating cost savings were calculated.

Indicative Measure on Reducing Drugs Wastage

This measure was not included in the MAC Curves in the main body of this report because there is a lack of evidence of the carbon and cost savings possible from reducing drugs wastage in the NHS. In this section we describe a possible method for illustrating the effect of a five percent reduction in drugs wastage, and how this would appear in a MACC.

For reducing drug wastage, the baseline CO_2 emissions for 2015 could be calculated by multiplying two projected figures from the SEI/Arup report:

- the carbon intensity of production of the pharmaceutical sector in 2015 (kg CO_2/£)
- the projected spend on the pharmaceutical sector in 2015 (£)

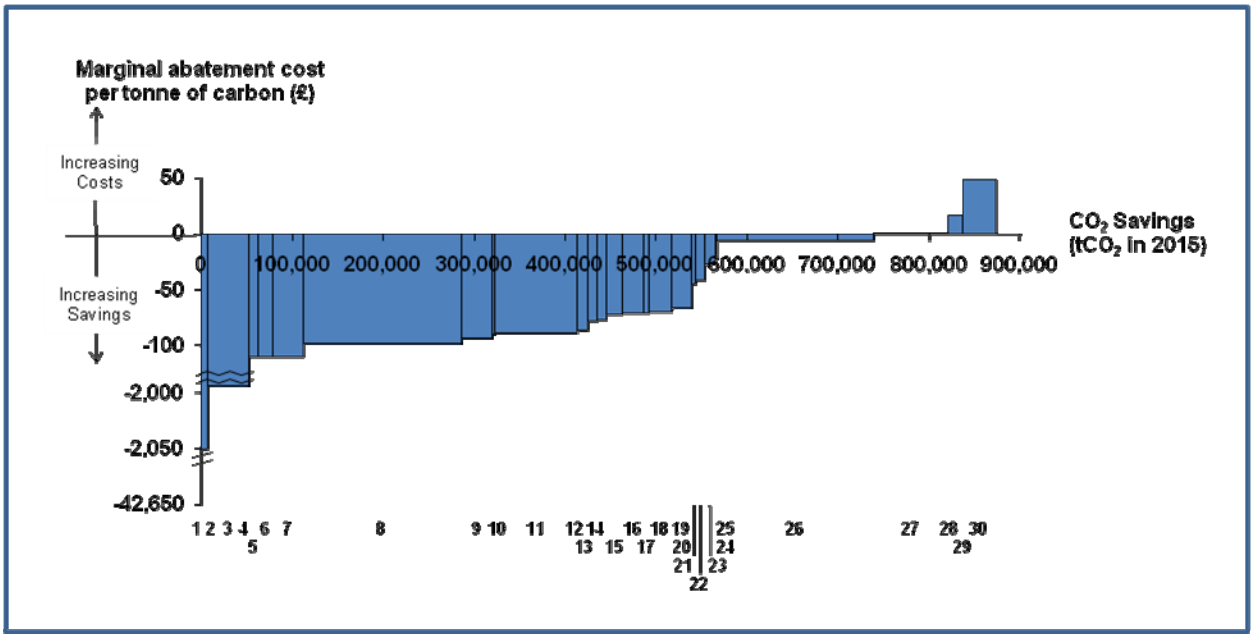
An assumption could be made that pharmaceutical procurement could be reduced by five percent through cutting wastage. The projected spend in 2015 on pharmaceutical sector can taken from the SEI/Arup report. Five percent of this cost can be estimated to be the annual operating cost saving for this option. These operating costs also factor in the additional cost of annual programme administration, needed to maintain the reduced waste of pharmaceuticals.

The carbon savings for this option can be estimated by multiplying the financial saving made by reducing drug spend by five percent, by the carbon intensity of production of the pharmaceutical sector (kg CO_2/£), which is also obtained from the SEI/Arup report.

The capital costs associated with this procurement option are entirely based on the staff time involved. An assumption was made that a Procurement Director at each NHS Trust would be charged with setting up the programme, taking six months to set it up.

The inclusion of this indicative measure would change the overall MAC Curve (Figure 7) to the following.

MACC for NHS England including Indicative Measure to Reduce Drugs Wastage by 5%



Option		£/tCO$_2$	CO$_2$ savings (tCO$_2$ in 2015)
1	Packaging	-42617	2
2	Teleconferencing	-2051	6,827
3	Reduce drug wastage	-1994	44,860
4	Introduce hibernation system for stations	-120	1,255
5	Improve the efficiency of chillers	-110	9,133
6	Voltage optimisation	-110	16,828
7	1 degree C	-110	32,763
8	CHP installation	-98	173,975
9	Improve lighting controls	-94	34,286
10	Variable speed drives	-90	3,083
11	Energy awareness campaign	-89	90,265
12	Building management system optimisation	-86	11,521
13	Improve insulation to pipe work, and/in boiler house	-79	10,264
14	Decentralisation of hot water boilers	-77	10,612
15	Improve heating controls	-72	17,219
16	Roof insulation	-71	22,869
17	Improve the efficiency of steam plant or hot water boiler plant	-71	6,367
18	Wall insulation	-70	24,624
19	Energy efficient lighting	-67	22,290
20	Upgrade garage and workshop heating	-60	214
21	Install high efficiency lighting and intelligent lighting controls	-45	3,745
22	Wind turbine	-42	10,722
23	Insulation - window glazing and draught proofing	-27	11,831
24	Improve building insulation levels (U-levels)	-19	951
25	Boiler replacement/optimisation for HQ/control centres	-15	171
26	Biomass boiler	-6	172,724
27	Travel planning	1	81,524
28	Office electrical equipment improvements	17	15,900
29	Solar hot water	49	0
30	Electric vehicles	49	36,969
Total annual CO$_2$ savings in 2015 – all measures			873,795

Appendix 3

Detailed costs and CO_2 savings

The following tables summarise our results in terms of financial costs and CO_2 savings for each measure in each category of Trust, and for the NHS level transport and procurement options. In each case the data are given for the costs and savings to the Trust category as a whole. To translate results for a Trust category into results for a single Trust in that category, you would divide by the relevant uptake rate and by the number of Trusts in each category, i.e. by 66 for Large Acute Trusts; by 103 for Small/Medium Acute Trusts; by 211 for Non-Acute/PCTs and by 11 for Ambulance Trusts.

These results are presented in two ways and so there are two tables for each Trust category. The first shows the results if we assume that there are no overlaps or interactions between measures and the second takes account of interactions and overlaps. The "with interactions" figures give a more realistic picture of what could be achieved in practice.

Table A6: Costs and carbon savings for Large Acute Trusts category – no interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Energy efficient lighting	4,950,000	-9,462,779	9,018	63,124	-£71
Improve lighting controls	7,128,000	-42,250,359	16,232	357,101	-£98
Energy Awareness Campaign	1,287,000	-12,756,087	35,519	106,556	-£108
1 degree C	0	-6,568,882	18,394	55,182	-£119
Improve the efficiency of steam plant or hot water boiler plant	5,280,000	-18,799,800	11,036	187,619	-£72
Biomass Boiler	31,680,000	-38,931,600	95,577	1,624,811	-£4
Improve the efficiency of chillers	1,237,500	-20,538,369	7,890	173,591	-£111
Building Management System optimisation	1,980,000	-9,859,011	4,085	89,867	-£88
Improve Heating controls	2,640,000	-16,903,705	8,277	182,101	-£78
Roof insulation	2,640,000	-20,284,445	9,933	218,521	-£81
Wall insulation	3,960,000	-22,538,273	11,036	242,802	-£77
Insulation - window glazing and draught proofing	6,600,000	-11,269,136	5,518	121,401	-£38
Improve Insulation to pipe work, and/in boiler house	1,320,000	-11,269,136	5,518	121,401	-£82
Variable Speed Drives	1,237,500	-3,217,664	2,254	22,544	-£88
Voltage optimisation	1,485,000	-28,166,906	10,821	238,067	-£112
CHP installation	53,046,005	-156,950,380	105,956	1,059,563	-£98
Solar Hot Water	5,482,973	-3,376,476	1,725	43,128	£49
Wind turbine	10,850,000	-20,898,375	7,643	191,086	-£53

Table A7: Costs and carbon savings for Large Acute Trusts category – with interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Energy efficient lighting	4,950,000	-9,462,779	9,018	63,124	-71
Improve lighting controls	7,128,000	-42,250,359	16,232	357,101	-98
Energy Awareness Campaign	1,287,000	-12,756,087	35,519	106,556	-108
1 degree C	0	-5,911,994	16,555	49,664	-119
Improve the efficiency of steam plant or hot water boiler plant	0	0	0	0	N/A
Biomass Boiler	31,680,000	-35,038,440	86,019	1,462,330	-2
Improve the efficiency of chillers	1,237,500	-20,538,369	7,890	173,591	-111
Building Management System optimisation	1,980,000	-8,873,109	3,676	80,880	-85
Improve Heating controls	2,640,000	-15,213,334	7,450	163,891	-77
Roof insulation	2,640,000	-20,284,445	9,933	218,521	-81
Wall insulation	3,960,000	-22,538,273	11,036	242,802	-77
Insulation - window glazing and draught proofing	6,600,000	-11,269,136	5,518	121,401	-38
Improve Insulation to pipe work, and/in boiler house	1,320,000	-11,269,136	5,518	121,401	-82
Variable Speed Drives	1,237,500	-3,217,664	2,254	22,544	-88
Voltage optimisation	1,485,000	-28,166,906	10,821	238,067	-112
CHP installation	53,046,005	-141,255,342	95,361	953,607	-93
Solar Hot Water	0	0	0	0	N/A
Wind turbine	10,850,000	-20,898,375	7,643	191,086	-53

Table A8: Costs and carbon savings for Small/Medium Acute Trusts category – no interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Energy efficient lighting	2,575,000	-5,793,882	5,521	38,650	-£83
Improve lighting controls	4,815,250	-23,713,344	9,110	200,426	-£94
Energy Awareness Campaign	1,429,125	-7,406,108	23,239	69,717	-£86
1 degree C	0	-3,005,194	9,614	28,843	-£104
Improve the efficiency of steam plant or hot water boiler plant	2,060,000	-6,066,260	3,605	61,291	-£65
Biomass Boiler	16,686,000	-20,505,451	50,965	866,398	-£4
Improve the efficiency of chillers	386,250	-3,233,638	1,242	27,331	-£104
Building Management System optimisation	2,317,500	-11,532,065	4,755	104,609	-£88
Improve Heating controls	1,545,000	-8,727,094	4,326	95,181	-£75
Roof insulation	2,472,000	-11,636,125	5,769	126,907	-£72
Wall insulation	2,884,000	-11,636,125	5,769	126,907	-£69
Insulation - window glazing and draught proofing	3,090,000	-4,848,385	2,404	52,878	-£33
Improve Insulation to pipe work, and/in boiler house	824,000	-5,818,062	2,884	63,454	-£79
Variable Speed Drives	386,250	-1,182,069	828	8,282	-£96
Voltage optimisation	1,030,000	-11,497,379	4,417	97,176	-£108
CHP installation	41,429,094	-122,578,732	82,752	827,522	-£98
Solar Hot Water	5,134,057	-3,161,609	1,635	40,884	£48
Wind turbine	7,425,000	-8,552,155	3,075	76,871	-£15

Table A9: Costs and carbon savings for Small/Medium Acute Trusts category – with interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Energy efficient lighting	2,575,000	-5,793,882	5,521	38,650	-83
Improve lighting controls	4,815,250	-23,713,344	9,110	200,426	-94
Energy Awareness Campaign	1,429,125	-7,035,802	22,077	66,231	-85
1 degree C	0	-2,854,934	9,133	27,400	-104
Improve the efficiency of steam plant or hot water boiler plant	0	0	0	0	N/A
Biomass Boiler	16,686,000	-19,480,178	48,416	823,078	-3
Improve the efficiency of chillers	386,250	-3,233,638	1,242	27,331	-104
Building Management System optimisation	2,317,500	-10,955,462	4,517	99,378	-87
Improve Heating controls	1,545,000	-8,290,739	4,110	90,422	-75
Roof insulation	2,472,000	-11,636,125	5,769	126,907	-72
Wall insulation	2,884,000	-11,636,125	5,769	126,907	-69
Insulation - window glazing and draught proofing	3,090,000	-4,848,385	2,404	52,878	-33
Improve Insulation to pipe work, and/in boiler house	824,000	-5,818,062	2,884	63,454	-79
Variable Speed Drives	386,250	-1,182,069	828	8,282	-96
Voltage optimisation	1,030,000	-11,497,379	4,417	97,176	-108
CHP installation	41,429,094	-116,449,796	78,615	786,146	-95
Solar Hot Water	0	0	0	0	N/A
Wind turbine	7,425,000	-8,552,155	3,075	76,871	-15

Table A10: Costs and carbon savings for Non-Acute/PCTs category – no interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Energy efficient lighting	5,486,000	-8,133,765	7,751	54,258	-£49
Improve lighting controls	6,330,000	-23,279,772	8,944	196,761	-£86
Energy Awareness Campaign	1,519,200	-7,982,531	30,995	92,986	-£70
1 degree C	0	-2,092,997	7,447	22,341	-£94
Improve the efficiency of steam plant or hot water boiler plant	4,114,500	-14,236,469	8,378	142,426	-£71
Biomass Boiler	8,440,000	-16,625,665	38,288	650,899	-£13
Decentralisation of hot water boilers	5,275,000	-19,322,702	13,963	181,523	-£77
Office electrical equipment improvements	8,440,000	-7,644,776	15,900	47,700	£17
Building Management System optimisation	2,110,000	-8,483,605	3,502	77,045	-£83
Improve Heating controls	4,220,000	-12,136,882	5,958	131,069	-£60
Roof insulation	5,538,750	-14,602,187	7,168	157,693	-£57
Wall insulation	5,538,750	-15,929,658	7,819	172,028	-£60
Insulation - window glazing and draught proofing	7,385,000	-7,964,829	3,910	86,014	-£7
Improve Insulation to pipe work, and/in boiler house	949,500	-3,792,776	1,862	40,959	-£69
Voltage optimisation	527,500	-4,138,626	1,590	34,980	-£103
Solar Hot Water	5,258,670	-3,238,347	1,659	41,465	£49
Wind turbine	31,650	-7,291	4	78	£313

Table A11: Costs and carbon savings for Non-Acute/PCTs category – with interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Energy efficient lighting	5,486,000	-8,133,765	7,751	54,258	-49
Improve lighting controls	6,330,000	-23,279,772	8,944	196,761	-86
Energy Awareness Campaign	1,519,200	-7,982,531	30,995	92,986	-70
1 degree C	0	-1,988,347	7,075	21,224	-94
Improve the efficiency of steam plant or hot water boiler plant	4,114,500	-10,819,716	6,367	108,244	-62
Biomass Boiler	8,440,000	-16,625,665	38,288	650,899	-13
Decentralisation of hot water boilers	5,275,000	-14,685,253	10,612	137,958	-68
Office electrical equipment improvements	8,440,000	-7,644,776	15,900	47,700	17
Building Management System optimisation	2,110,000	-8,059,424	3,327	73,193	-81
Improve Heating controls	4,220,000	-11,530,038	5,660	124,516	-59
Roof insulation	5,538,750	-14,602,187	7,168	157,693	-57
Wall insulation	5,538,750	-15,929,658	7,819	172,028	-60
Insulation - window glazing and draught proofing	7,385,000	-7,964,829	3,910	86,014	-7
Improve Insulation to pipe work, and/in boiler house	949,500	-3,792,776	1,862	40,959	-69
Voltage optimisation	527,500	-4,138,626	1,590	34,980	-103
Solar Hot Water	0	0	0	0	N/A
Wind turbine	31,650	-7,291	4	78	313

Table A12: Costs and carbon savings for Ambulance Trusts category – no interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Improve building insulation levels (U-levels)	330,000	-729,918	951	20,913	-£19
Install high efficiency lighting and intelligent lighting controls	153,863	-1,324,181	3,745	26,215	-£45
Upgrade garage and workshop heating	110,000	-392,070	214	4,705	-£60
Boiler replacement/optimisation for HQ/control centres	19,800	-75,077	171	3,764	-£15
Introduce hibernation system for stations	140,800	-2,407,139	1,255	18,828	-£120
Energy Awareness Campaign	79,200	-775,754	1,674	6,694	-£104

Table A13: Costs and carbon savings for Ambulance Trusts category – with interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Improve building insulation levels (U-levels)	330,000	-729,918	951	20,913	-19
Install high efficiency lighting and intelligent lighting controls	153,863	-1,324,181	3,745	26,215	-45
Upgrade garage and workshop heating	110,000	-392,070	214	4,705	-60
Boiler replacement/optimisation for HQ/control centres	19,800	-75,077	171	3,764	-15
Introduce hibernation system for stations	140,800	-2,407,139	1,255	18,828	-120
Energy Awareness Campaign	79,200	-775,754	1,674	6,694	-104

Table A14: Costs and carbon savings for other options – no interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Travel Planning	340,000	504,319	81,524	815,237	£1
Electric Vehicles	80,880,541	-58,143,794	38,915	466,976	£49
Teleconferencing	4,301,000	-102,326,162	6,827	47,790	-£2,051
Packaging	242,212	-720,506	2	11	-£42,617

Table A15: Costs and carbon savings for other options – with interactions

Name of measure	Net Present Value (£)		CO_2 savings (tonnes)		Cost-effectiveness (£/tCO_2)
	Capital costs	Operating costs	Annual	Lifetime	
Travel Planning	340,000	504,319	81,524	815,237	1
Electric Vehicles	80,880,541	-55,236,605	36,969	443,628	58
Teleconferencing	4,301,000	-102,326,162	6,827	47,790	-2051
Reduce drug wastage	1,992,400	-449,328,982	44,860	224,298	-1994
Packaging	242,212	-720,506	2	11	-42617

AEA group
329 Harwell
Didcot
Oxfordshire
OX11 0QJ

Tel: 0870 190 6487
Fax: 0870 190 6318