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Modelling the 2013-18 Cap for the CRC Energy Efficiency Scheme (CRC)

FINAL REPORT

- Final
- July 2010

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1. Abbreviations

ACE	All Cost Effective
BAU	Business As Usual
BREDEM	Building Research Establishment's Domestic Energy Model
CCA	Climate Change Agreement
CCC	Committee on Climate Change
CCL	Climate Change Levy CO2
CO2	Carbon dioxide
CRC	CRC Energy Efficiency Scheme
CT	Carbon Trust
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
EA	Environment Agency
EEC	Energy Efficiency Commitment
ENUSIM	Industrial Energy End Use Simulation Model
EPBD	Energy Performance of Buildings Directive
EUA	EU Emissions Trading System CO_2 Allowances
EU ETS	European Emissions Trading System
FITs	Feed-In Tariffs
GHG	Greenhouse Gas
HHM	Half Hourly Meter
IA	Impact Assessment
M&T	Monitoring and Targeting
MACC	Marginal Abatement Cost Curve
MOD	Ministry of Defence
MtC	million tonnes of carbon
MtCO2	million tonnes of carbon dioxide equivalent
MTP	Market Transformation Programme
MWh	Megawatt Hour
N-DEEM	Non-Domestic buildings Energy and Emissions Model
NHS	National Health Service
RH	Renewable heat
ROC	Renewable Obligation Certificate
SIC	Standard Industrial Classification
UK ETS	UK Emissions Trading Scheme

2. Headline findings

Table 1 Summary of cap outputs for the CCC Central scenario

CCC Central scenario, high 6,000MWh threshold	MtCO2	
Base year emissions 2009	Total 73.5	Public sector 17.1 Private commercial sector 33.1 Private industry sector 22.9
BAU projection for 2017	75	
BAU projection for 2022	77	
Carbon savings for 2017	Total 16.0 (plus 0.1 renewables)	13.8 from electricity 2.24 from fossil fuel
Carbon savings for 2022	Total 23.3 (plus 1.4 renewables)	20.1 from electricity 3.2 from fossil fuel
Phase 1 cap excluding renewables	59	
Phase 1 cap including renewables	59	
Phase 2 cap excluding renewables	53.6	
Phase 2 cap including renewables	52.2	

Table 2 Summary of recommended next steps

Recommendations type	Next steps
Base year emissions	Use real data when available
CRC specific modelling: sectors	Use real data and new CRC sector structure for collection and analysis of registration and subsequent years' data
CRC specific modelling: carbon savings	Develop modelling to address CRC specific issues e.g. complete technology list and accurate uptake rates
CRC specific modelling: savings from renewable	Provide more clarity on handling rules within CRC and between CRC, RHI and FITs Some specific CRC specific renewables modelling
Cap setting guidance	Provide estimated % reduction required from sectors in late 2010/ early 2011 Set absolute and firm cap on the basis of two years' real data in summer 2012

3. Executive Summary

Introduction

1) This report summarises the results of a study into the setting of the cap for the Carbon Reduction Commitment Energy Efficiency Scheme (CRC). The study was carried out for the Committee on Climate Change (CCC) between January and May 2010. The research and analysis was carried out by a team from SKM Enviros, Ecofys and Entec UK.
2) The objective of the study is to provide the CCC with advice about the CRC during the first two capped phases, between 2013 and 2022, and to provide a modelling tool for cap analysis.
3) The outputs from the study include a spreadsheet based modelling tool (with detailed user guidance) as well as this main project report.
4) The study included a detailed assessment of previous studies and abatement models of relevance to CRC cap setting. Outputs from previous work were used as a basis for updated or improved abatement models.
5) Some significant improvements have been made to some aspects of previous modelling:

   (a) the selective mapping of ENUSIM sectors to CRC sectors;

   (b) the segregation of ENUSIM and N-DEEM technologies into four groups to enable differentiated uptake rates to be applied to them; and,

   (c) the use of relative rather than absolute abatement potentials.

6) Within the limited resources available for this work the basic modelling of CO_2 emission abatement potential in this study relies on two existing models (ENUSIM for industrial sectors and N-DEEM for non-domestic buildings) that have been used previously for a range of UK Government climate change policy assessments. Our analysis has shown that the outputs from these models are unlikely to give a sufficiently accurate assessment of abatement potential for CRC participants. Hence the cap estimates presented in this report must be treated with great caution and any caps suggested from this evidence should take this uncertainty into account.

Existing Evidence Review

7) Section 5 of this report provides a review of previous CRC reports, related studies and of the corresponding modelling tools. A total of 16 studies and models were reviewed and the results of these reviews are written in to the main report body.
8) The analysis of previous work identified two major issues. Firstly, the way that the CRC baseline (i.e. emissions from all CRC participants in the first year of the CRC) had been estimated was inadequate for cap setting. Secondly, the outputs from the available emission

abatement potential assessment tools were inadequate from a CRC perspective. These shortcomings are discussed below and recommendations for improvements have been made.

Requirements for Good CRC Cap Setting

9) The ultimate success of the CRC relies on good cap setting. Previous emissions trading schemes have shown the danger of setting an "easy" cap, which leads to a collapse in the price of CO_2 and little or no emission reduction (e.g. UK ETS, EU ETS Phase 1). Conversely, a cap that is too tight in the absence of a safety valve mechanism will place unfair burdens on CRC participants who would need to make investments in excessively expensive abatement projects to meet the cap. The CRC will have maximum impact and credibility if these opposite extremes are avoided.

10) The basic requirements for setting a good cap are described in section 6, together with an assessment of the capability of existing modelling tools. This section emphasises the need for:

   a) an accurate baseline or base year i.e. the quantity of emissions now;
   b) an accurate assessment of projected emissions out to 2022 (from the base year) under business as usual (BAU) i.e. the future growth in the quantity of emissions;
   c) an accurate assessment of the overall level of abatement potential;
   d) an accurate assessment of the likely rate of uptake of that potential; and,
   e) a methodology to deal with overlaps with other abatement policies and influencing factors.

11) It is useful to note the interaction between the way that the baseline is identified and the way that abatement modelling is carried out. Abatement opportunities are highly sector specific. The way in which we select the sectors and subsectors not only affects baseline analysis but also the way in which we are then able to conduct the abatement modelling. For example if the retail sector is identified in the baseline at this aggregate level rather than for subsectors of retail, abatement potential will not necessarily pick up on the variation in the opportunities and therefore savings which might be attributed to the different retail subsectors.

Baseline Emissions Assessment

12) Section 7 describes an improved approach to assessing the baseline emissions.

13) In this project, the sectors which were defined and used in previous studies have been modified to provide better granularity in large heterogeneous sectors. The new sector structure also provides high level groupings that make it easier to understand the potential in major areas of the economy (public sector, private sector commercial and private sector industrial). It is

recommended that the sectors defined in this section are used as a basis for both baseline estimates and for abatement modelling. It will be important that the CRC administrators "map" each participant into the relevant sector when they register so that the data estimated in this study can be updated with real data in 2011.

14) Data from the UK Digest of Energy Statistics (DUKES) has been used to establish the total UK emissions from each sector. An estimate of CRC coverage has been made by subtracting the following from the gross sector figure: (a) EU ETS and CCA coverage, (b) CCA 25% rule exclusions and (c) the proportion of emissions from organisations that are below the CRC threshold of 6,000 MWh.

15) This analysis has provided an overall estimate of CRC coverage between 61.2 and 73.5 $MtCO_2$. This new estimate is higher than previous studies because there have been a number of policy changes since 2006 when the first coverage estimates were made e.g. the change in CRC threshold and the introduction of the CCA 25% rule. It shows less coverage in industrial sectors but higher coverage in the commercial and public sectors. A high and low scenario has been evaluated because of the uncertainties in the baseline evaluation described below. Base year emissions estimates have also been evaluated for a 3,000 MWh CRC threshold.

16) These new baseline estimates have been used as a basis for cap calculations using the new modelling tool. They provide a good platform for scenario modelling. However, it must be stressed that the base year estimate is not accurate enough for cap setting. The prime reasons for lack of accuracy are the difficulty in assessing (a) the impact of the CCA 25% exclusion rule and (b) the proportion of emissions below the 6,000 MWh threshold. There are also some concerns over the accuracy of the DUKES data. We do not recommend that further work is done to model the base year emissions – even if a major study was done, modelling would not be accurate enough to overcome the difficulties just described. The best approach will be to use the two years' worth of actual CRC data when it becomes available in July 2012.

17) The problems in identifying an accurate baseline were recognised in the Enviros/ NERA report (2006). This is one of the reasons that the CRC was designed with a 3 year introductory phase. It is vital that real CRC data is used to establish a new baseline before the cap is set. Data for the first CRC year (April 2010 to March 2011) will be available in the summer of 2011. Data for the second year will be available in summer 2012. Previous experience from similar schemes (e.g. CCAs) indicates that the first year of data may contain many mistakes, so it is strongly recommended that the final decision about an absolute level of cap is not made until the second year of data becomes available. An indicative % reduction could be announced earlier, but this needs to be applied to the most accurate available baseline to establish the absolute cap level.

18) An important aspect of the CRC sector analysis is an improved understanding of the modelling of the heavy industrial sectors with significant CCA coverage. Our research shows that many large companies will be in both CCAs and the CRC (despite the CCA 25% exclusion rule). However, the parts of such a business that are in the CRC bear little or no relationship to the main activities of the industrial company. For example, the parts left in the CRC might be offices or depots. This means that the ENUSIM models for the relevant industry sector are not relevant. This is discussed in Section 7. The CRC parts of these companies have been described as "industry fragments" and modelled as if they are either a commercial office or a light engineering type of organisation.

19) The sector analysis in section 6 also identifies the possibility of certain CRC participants being "multi-sector" organisations that will be difficult to model. The best example is Local Authorities that carry out a wide range of heterogeneous activities.

Modelling the Emission Abatement Potential

20) Section 6 provides an overview of what is needed in a good modelling tool and it identifies the key inadequacies of the ENUSIM and N-DEEM tools when applied to the CRC sectors. The most important aspects that are missing from the current modelling tools are:

- **Accurate modelling of abatement potential in the main CRC sectors and subsectors.** Previous ENUSIM work has concentrated on "heavy" industrial processes rather than the less energy intensive non-CCA industries. N-DEEM provides a very out dated assessment and no granularity between widely differing sectors (e.g. the potential estimated for offices, supermarkets and hospitals is based on the same list of technologies). Little research has been done in recent years to assess the current market penetration of key technologies in CRC sectors. There are serious doubts from the CRC perspective about the accuracy of the outputs from both of these models.
- **Modelling of the rate of uptake of abatement technologies.** The MACCs from ENUSIM and N-DEEM show the potential available in a given year (i.e. available to be taken up at any time from that year onwards), but not how much of that potential that will be taken up over a discrete time period.
- **Assessment of all relevant opportunities.** All types of efficiency measure need to be evaluated together with low carbon energy supply options. Comprehensive assessments of this type are not available for CRC sectors in ENUSIM since ENUSIM does not include energy supply measures or N-DEEM since N-DEEM includes renewable electricity but not renewable heat measures.

- **Taking technology change into account.** The modelling needs to be flexible enough to take into account new energy saving technologies. ENUSIM and N-DEEM are both "static" in terms of the technologies evaluated.

21) Theses weaknesses cannot be addressed without a major rethink regarding modelling tools and how they are applied. A key recommendation from this study is that CCC and DECC consider improved CRC specific emission abatement modelling.

22) Section 8 describes the basis of the emission abatement modelling carried out in this study. It has provided some useful outputs, especially in relation to an improved understanding of the sectors that require modelling and the influencing parameters that must be taken into account. The outputs must be treated with great care given the concerns about the ENUSIM and N-DEEM tools,

23) A key improvement made to previous modelling has been the application of a "rate of uptake" modelling approach.

The New CRC Cap Modelling Tool

24) Section 8 describes the modelling tool written for the CCC during this project. The tool is an Excel spreadsheet and is accompanied by detailed guidance.

25) The objective was to provide a user friendly tool that allows the CCC to vary many of the influencing parameters that may affect the cap and produce outputs that predict the abatement potential each year to 2022.

26) The model is based on an improved disaggregation to the CRC sectors recommended in section 6. The baseline emissions from each sector are the values estimated in this study. These can be quickly updated when real data is available at the end of the first and second year of the CRC.

27) The model calculates the emission abatement potential using outputs from ENUSIM and N-DEEM for energy efficiency projects and from a number of recent studies for renewable heat and electricity modelling. The concerns described above in the accuracy of these models means the model outputs must be used with caution. The model has been designed for the easy replacement of the "core calculation worksheets" should improved abatement modelling results become available.

28) A wide range of parameters can flexibly be changed by the user for each run of the model. These include price of CO_2, fuel price, discount rate, carbon conversion factors, sector growth rates and technology uptake rates.

Evaluation of Cap Scenarios

29) Section 9 summarises the results of numerous runs of the CRC cap model carried out during the project.

30) A "central" scenario uses a cost of abatement price of £0/tonne (also referred to as CO_2 price which in this work is not the EU ETS price) , a discount rate of 3.5%, central energy prices (based on DECC projections), medium rate of technology penetration and DECC estimates of growth rates. This scenario shows a realistic cost effective energy efficiency abatement potential of 21% by 2017 and 32% by 2022. Sensitivity analysis was carried out for each of the parameters described above. The results are given in section 10.

31) Varying the key economic parameters (i.e. price of CO_2, fuel price and discount rate) did not change the estimated level of energy efficiency abatement. This is counter intuitive and is caused by the inadequate nature of the ENUSIM and N-DEEM outputs.

Supporting Measures

32) Section 11 reviews barriers to the uptake of emission abatement technologies. The analysis describes the various reasons why many CRC organisations do not maximise the cost effective abatement that they could achieve.

33) It is expected that the CRC itself will provide strong drivers to overcome these barriers, providing the cap is set at the correct level. The "reputational levers" in the CRC, linked to the performance league table, will add to the effectiveness of a well capped scheme.

34) A number of support measures are described, such as sector specific guidance and financial support for measures such as monitoring and targeting. Implementation of such measures may have the greatest impact on achieving carbon savings and help to maximise the success of the CRC.

Next Steps

35) Section 12 summarises the recommendations for further work that is required to ensure that a CRC cap can be set using accurate information. The main tasks that need to be carried out relate to improved modelling of abatement potential, both for energy efficiency measures and for renewable electricity and heat opportunities.

36) It is recommended that the CRC sectors described in section 7 are used as a basis for both baseline data collection and for abatement modelling. A more accurate baseline must be established using real CRC data rather than being based on modelling. It will be important to get a split of baseline data for each CRC sector. Sector level data showing the split between

electricity and other fuel types should also be assessed. The CRC Administrators (Environment Agency (EA)) must be asked to collect information from each registering CRC participant that will identify the appropriate CRC sector. A provisional baseline should be set in summer 2011, based on the first year of real footprint data. This should be reviewed in summer 2012 using the second year of data before the cap is set.

37) The most important next steps relate to developing improved emission abatement potential models. These are required for specific sectors including water and the non-domestic sectors. It may be appropriate to develop technology specific modelling.

38) A new methodology for developing MACCs for CRC sectors must be carefully considered before the modelling begins. The current methodologies used in ENUSIM and N-DEEM seem to be insensitive to key drivers and inflexible to technology change. It may be possible to develop a new approach that avoids some of these difficulties.

39) There has been very little research about penetration of efficiency technologies into key CRC sectors carried out in recent years. This will be an important starting point for any new modelling work.

40) New modelling must provide a realistic assessment to rates of technology uptake. It is recommended that the method of splitting opportunities into groups with different uptake characteristics (see section 6.5) is developed to provide this functionality.

41) New modelling should attempt to model potential technology change. Opportunities that are currently not cost effective may be viable in 5 to 10 years time and will impact the caps in the second capped phase of the CRC.

42) When improved modelling has been completed the outputs should be formatted to act as the "core calculation worksheets" for the CCC spreadsheet model.

4. Introduction

4.1. Introduction

This report presents the findings of research completed by SKM Enviros Consulting, Ecofys and Entec UK on behalf of the Committee on Climate Change (CCC). It aims to provide analysis and recommendations to advise the CCC on the level of the cap for the first two capped phases of the CRC (2013 to 2017 and 2018 to 2022[1]). The research was carried out in Quarter 1 of 2010.

4.2. Background

The CRC aims to incentivise absolute carbon emissions reductions in large organisations that are not already targeted under CCAs or the EU ETS. Participants are defined as public or private sector organisations that:

- have at least one meter settled on the 'half-hourly market'; and,
- have qualifying electricity supplies through half-hourly meters (HHMs) of over 6,000MWh in calendar year 2008.

From April 2010, participants will need to monitor and report their use of electricity and fossil fuels to Government. They will also be asked to buy carbon allowances to cover those emissions, initially at a sale (for the years 2011 and 2012 of the introductory phase) and subsequently at auction (from 2013). Once auctioning begins, a 'cap' on annual emissions from participants will be implemented by limiting the number of allowances available at the annual auction.

CRC rules[2] require CRC allowances to be bought for electricity used by an organisation which was generated from renewable sources where ROCs or FITS are claimed. This is because the emphasis of the CRC is on energy efficiency improvements rather than providing further incentives for renewable energy generation.

The CRC will include a safety valve mechanism to protect against the price of allowances becoming too high. Through this, CRC participants can ask the administrator to issue extra allowances throughout the year. The price of the safety valve is related to the price of allowances in the European Emissions Trading System, but is always greater than buying allowances through the fixed price Government sale. Since February 2010 the minimum safety valve price has been set at £14. Safety valve allowances will therefore not be sold for less than £14, even if the EU ETS market should be trading below this.

[1] Please note that each CRC year runs from April to March. Throughout this report we refer to a CRC year as a single year e.g. 2013. This refers to the CRC year from April 2013 to March 2014.
[2] Taken from the January 2010 version of the CRC User Guide and set out in The CRC Energy Efficiency Scheme Order 2010

4.3. Role of the Cap

The cap will define the maximum number of CO_2 allowances that will be auctioned in each year of the CRC. As we have seen in other emissions trading schemes (like the EU Emissions Trading System and the UK Emissions Trading Scheme), the level of the cap will be a key determinant of the success of the scheme. If it is set too high, the scheme will deliver only limited additional carbon savings. If it is set too low and in the absence of a safety valve mechanism, participants will be required to reduce their emissions further than may be cost effective or further than those organisations captured by other policies are required to do. This would be inefficient and inequitable. Inefficient because the CRC has been designed to enable system participants to make the savings in the most cost effective way. This is either through making the carbon savings themselves or buying allowances from other participants that have been able to make those savings. Inequitable because CRC participants may need to invest at higher rate of £ per tonne CO_2 saved than companies covered by other policies such as CCAs and the EU ETS[3].

In the interests of promoting fairness and equity across participants, the CRC will include a safety valve mechanism to protect against the price of allowances becoming too high. The EU ETS safety valve allowance price is related to the price of allowances in the European Emissions Trading System, but is always greater than buying allowances through the fixed price Government sale. Safety valve allowances will not be sold for less than £14, even if the EU ETS market should be trading below this. It is therefore in the financial interests of participants to purchase allowances through the safety valve only if CRC allowances for sale on the secondary market are more expensive than EU ETS allowances (and accounting for the respective fees and charges for acquiring allowances via each route).[4]

4.4. Role of This Project

The purpose of this project is to build on existing analysis to help inform the CCC's work on their advice on the cap. It follows earlier work by the project team and other organisations to ascertain who will be covered by the scheme, their emissions, abatement options and the costs of those carbon savings. It is based on information provided by the CCC plus other published information and analysis.

4.5. Objectives, Approach and Deliverables

The overriding objective of this project is to advise the CCC on the level of cap for the CRC for 2013 to 2022. The recommendations are based on quantitative analysis of the available evidence with explanation of the uncertainties around the recommendations.

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[3] Note that the safety valve will help to counter this potential effect
[4] CRC User Guide (January 2010)

Our approach is based on:

- building on (rather than replicating) the existing evidence base;
- taking the analysis forward by assessing the assumptions on which the quantification is based and by further exploring the factors that affect the cap level;
- considering a range of possible cap levels through scenario analysis; and,
- providing the CCC with a tool that allows it to undertake further analysis in future, accommodating new data on the CRC as it becomes available e.g. from the first year of the Introductory Phase (2010 to 2011).

The outputs from this project are this final report and a spreadsheet tool with guidance notes that will allow the CCC to undertake on-going analysis of the cap.

4.6. Summary of Report Contents

- Section 5 provides the review of the existing evidence;
- Section 6 outlines key cap setting requirements;
- Section 7 provides details of how we have revised the estimated sizes of the CRC sectors and subsectors and structure of the CRC participants for modelling purposes;
- Section 8 describes the assumptions and amendments implemented for the modelling tool;
- Section 9 provides an overview of the modelling tool;
- Section 10 details the cap outputs from running the modelling for a range of scenarios;
- Section 11 discusses the types of measures which might be appropriate for incentivising uptake of energy efficiency measures from CRC participants; and,
- Section 12 draws together conclusions from the rest of the report to make recommendations for next steps for CCC to recommend a cap.
- Section 13 lists references.
- Appendices A to I provide further details about ENUSIM and N-DEEM, carbon saving estimates and assumptions, and energy efficiency barriers and incentives.

5. Existing evidence review and gap analysis

5.1. Introduction

A number of sources for CRC coverage and carbon savings estimates are already available. The purpose of the evidence review was to assess these existing estimates and supporting information, in order to answer the following questions:

- what information and models have been used to generate estimates of CRC coverage, carbon savings and abatement potential?
- what are the outputs of the studies and models?
- what are the limitations of the studies and models?

The existing studies and models were reviewed on the following basis:

- objectives, methodology and scope;
- assumptions, sectoral split and outputs (including coverage estimate, carbon savings and abatement potential).

Table 3 and Table 4 summarise the models and studies reviewed. More detailed summaries of the key items are provided in the appendices (i.e. on assumptions and outputs). Other material referenced in this report is footnoted and fully listed in section 13.

The lighter shaded studies in the following tables indicate those discussed in section 5 – which provide the basis for and the actual coverage and carbon savings estimates. The darker shaded studies indicate those which do not provide coverage and carbon savings estimate but have been reviewed for their usefulness in developing new modelling for this project.

The rest of section 5 covers the following:

- section 5.2: descriptions of the models and how they work, including CRC-relevant data updates, scenarios and outputs;
- section 5.3: CRC associated limitations with the models;
- section 5.4: comparisons of CRC coverage and carbon savings estimates including reasons for the differences;
- section 5.5: details of how low carbon generation carbon abatement potential has been variously included in CRC carbon savings estimates; and,
- section 5.6: concluding comments on previous models and studies.

Table 3 List of models reviewed

Study/ model number	Abbreviated name[5]	Model	Author, for or owned by	Year
1	N-DEEM	N-DEEM	Co-owned by BRE and DECC	1996, updated most recently in 2007-08
2	ENUSIM	ENUSIM	Owned by DECC	Late 1990s, updated most recently in 2010
3	CCC Non-domestic cost abatement MACC model 2008	Non-domestic cost abatement MACC model for the Review and update of UK abatement costs curves for the industrial, domestic, and non-domestic sectors	AEA, Ecofys and the Carbon Consortium for the CCC	August 2008
4	CCC Heat model 2009	Renewable Heat Technologies for carbon abatement potential	NERA, Entec and Element Energy for CCC	July 2009

Source: SKM Enviros, Ecofys, Entec UK (2010)

[5] Used from hereon in

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Table 4 List of studies reviewed

Study/ model number	Abbreviated name	Study	Author, for	Publication month, year
5	Enviros/ NERA 2006	Energy Efficiency and Trading Part II: Options for the implementation of a new mandatory UK emissions trading scheme	Enviros/ NERA for DEFRA	April 2006
6	DEFRA First consultation 2006	Consultation on measures to reduce carbon emissions in the large non-energy intensive business and public sectors	DEFRA	November 2006
7	DEFRA IA 2007	Consultation on implementation proposals for the Carbon Reduction Commitment	DEFRA	June 2007
8	CCC Review and update 2008	Review and update of UK abatement costs curves for the industrial, domestic, and non-domestic sectors	AEA, Ecofys and the Carbon Consortium for the CCC	August 2008
9	DEFRA Partial IA 2009	Updated regulatory impact assessment on the Carbon Reduction Commitment	DEFRA	March 2009
10	CCC Heat model report 2009	Renewable Heat Technologies for Carbon Abatement: Characteristics and Potential	NERA, Entec and Element Energy for CCC	July 2009
11	DECC Design of FITs 2009	Design of Feed-in Tariffs for Sub-5MW Electricity in Great Britain Quantitative analysis	DECC	July 2009
12	DECC RH supply curve 2009	The UK supply curve for renewable heat	NERA and AEA for DECC	July 2009
13	DECC Final IA 2009	Final Impact Assessment on the Order to Implement the Carbon Reduction Commitment Energy Efficiency Scheme	DECC	October 2009
14	EA 2009	The CRC Energy Efficiency Scheme: Coverage, Abatement & Future Caps	AEA for the EA	November 2009
15	CT 2009	Building the future today	Carbon Trust	December 2009
16	CT unpublished	Breaking through the barriers: unleashing energy efficiency in the UK	Carbon Trust	(Draft unpublished, January 2010)

Source: SKM Enviros, Ecofys, Entec UK (2010)

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5.2. Description of Emission Abatement Models

5.2.1. Introduction

All of the CRC studies reviewed rely on the outputs and databases from the Industrial Energy End Use Simulation Model (ENUSIM) and Non-Domestic Buildings Energy and Emissions Model (N-DEEM) to generate the existing CRC coverage and carbon savings estimates. This section outlines the key features of the two models, including:

- descriptions of the models;
- CRC relevant data updates;
- how the models work; and,
- scenarios and outputs.

This section also briefly describes an additional piece of modelling completed for CCC in 2008 which reviewed MACCs for the UK economy as a whole[6]. This is relevant because it created the functionality to create the CRC subsector within the modelling. This is discussed in more detail in section 5.2.7.

5.2.2. Model descriptions[7]

The Industrial Energy End Use Simulation Model (ENUSIM) is a bottom-up sectoral energy consumption model (i.e. demand side) of the UK industrial sector, with customised analysis by sector and subsector. The model simulates the uptake of energy efficiency technologies, given assumptions on the base year energy use, the technical detail of the technologies, projections of fuel prices and projections of growth rates.

The Non-Domestic Buildings Energy and Emissions Model (N-DEEM) is also a bottom-up model designed to assess the potential impact of individual energy efficiency measures in non-domestic buildings. It is based on the application of a simplified dynamic thermal simulation technique[8] to a building stock model that represents a range of different non-domestic building types across the UK. In the context of this study, N-DEEM is the non-domestic marginal abatement cost curve model developed by BRE and subsequently manipulated by AEA in 2008. As such N-DEEM here includes data from a variety of sources including the energy data from the Sheffield-Hallam survey of 700 buildings (in 1994) as well as other data accumulated from iterative communications with stakeholders over a 15 year period during a range of projects.

[6] CCC 2008
[7] More detailed descriptions of the models are included in Appendix A
[8] The technique calculates building energy requirements, see Appendix A

5.2.3. CRC relevant data updates

Since ENUSIM was first developed in the 1990s there has been significant investment into updating the model. This has not however included the CRC industrial sectors (including the water sector). The penetration curves have been updated (in early 2010) for a range of generic technologies and the applicable technologies data for aluminium and food. This 2010 update supports the forthcoming CCA negotiations for future target periods and does not help with modelling of carbon abatement in CRC sectors. Further information on ENUSIM updates is in Appendix A.

N-DEEM is based on a number of primary data sets and calculation tools which were compiled throughout the 1990s. There has been additional investment into N-DEEM updating some of the data used by the model but not specifically dealing with CRC sectors or relevant CRC sector technologies. For more detail on N-DEEM see Appendix A.

5.2.4. How the models work: avoiding double counting

ENUSIM and N-DEEM avoid the double counting of abatement potential through potentially overlapping measures using the following mechanisms.

ENUSIM identifies mutually exclusive measures. When a measure is implemented any mutually exclusive measures are then assumed to be unavailable. For example, if there are three technology options for plant replacement, they are tagged in ENUSIM as mutually exclusive, so that if one of the three technology options is taken up, then the other two technology options are removed.

N-DEEM considers:

- overlaps between **different measures** (i.e. across different types of measures, such as between roof insulation and double glazed windows) and;
- overlaps between **similar measures** (i.e. meaning measures within a measure type, such as different types of lighting or different types of windows).

The N-DEEM off-model is based on a previous run of the dynamic simulation model (3TC), described in Appendix A, which assesses the impacts of fabric measures and the thermal interaction between measures in a building (by building type). The outputs of this run (of the original simulation model) take into account overlaps between **different measures**. Because the N-DEEM off-model is based on the outputs of the combination scenario of 3TC, the off-model inherently takes into account overlaps between different measures. In addition, the NDEEM off-model provides its own mechanism to take into account overlaps between **similar measures**.

N-DEEM groups **similar measures** so that the abatement potential of same group measures is modelled according to the sequence in which the measures are implemented. Hence, the first measure will realise its full cost effective potential and the following measure will realise its cost effective potential out of the remaining cost effective potential.

For the public and commercial sectors in the model provided to CCC, there are therefore no overlaps between similar or different measures.

5.2.5. How the models work: S curves

ENUSIM simulates the uptake of cost-effective technologies by assuming that the penetration of each technology follows an 'S-curve'. As a technology enters the market its initial penetration rate is slow. The penetration rate increases as the market develops and slows as it approaches saturation. The 'S-curve' for each technology is specified by the final penetration and the time taken to reach maximum penetration. The user can also specify the point at which the technology can start along this curve, and as long as the technology remains cost-effective, the penetration of the technology will proceed smoothly along the remainder of the curve. The level at which the uptake of the technology saturates (i.e. the maximum technology penetration) can differ by technology.

ENUSIM calculates cost curves for individual energy saving technologies by taking the difference between the penetration of technologies in any given year under the BAU scenario, and the maximum technology penetration. This gap represents the remaining potential available for that technology and the specific cost (£/ tCO_2 saved). In the cost curve, this remaining potential is represented as a step in the curve. The calculation of this remaining potential does not take into account the amount of time over which the investments could be made cost-effectively. It therefore should not be assumed that the potential saving implied by the cost-curves can be implemented immediately. Appendix A gives further information about how ENUSIM works.

For each technology in N-DEEM there is an S curve penetration curve which varies between building types. Buildings types are associated with different sectors (e.g. hospitals with the health sector).

The energy models are then applied to a UK building stock model based on building type (activity/ sector), floor area data, typical building sizes and age. The energy consumption of the UK building stock as a whole is also cross-referenced with DECC energy statistics[9]. N-DEEM then allows the assessment of each of the energy efficiency measures in terms of the impact on the individual

[9] Digest of UK Energy Statistics, available from: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx, for N-DEEM this was last done based on 2006 statistics.

exemplar buildings, with adjustments for market penetration to determine the reduction potential under a range of different scenarios.

Cost effectiveness of abatement potential in both models is determined according to the assumptions made in a given scenario. Both models consider capital costs (including upfront capital, maintenance and operating costs) in their estimation of costs and cost effectiveness. Both models can operate with variable discount rates and fuel prices (generally provided by DECC). As explained above, the models avoid overestimation of abatement potential of competing or overlapping technologies for the same energy using process.

5.2.6. Scenarios and outputs

In both ENUSIM and N-DEEM the maximum penetration levels and penetration rates are adjusted for different scenarios. ENUSIM is set up to handle three scenarios including All Technically Possible (ATP), All Cost Effective (ACE) and Business as Usual (BAU) scenarios. N-DEEM provides technical potential and realistic potential. The analysis is based on a 'static' building stock, and therefore estimates the savings that are still available in the current building stock in future years[10]. Appendix A provides details of the ENUSIM scenarios.

Both the ENUSIM and N-DEEM off-models were set up to provide:

- projections of energy use in certain sectors[11] (ENUSIM only);
- projections of CO_2 emissions in a given year (ENUSIM only);
- emissions savings under different scenarios;
- emissions savings taking into account the uptake of cost effective abatement technologies in that sector;
- savings on a year-by-year basis (up to 2025 for ENUSIM and 2022 for N-DEEM); and,
- sector by sector MACCs for both CO_2 and energy (but not energy for the N-DEEM off-model) at given years (for both off-models this is abatement potential in 2012, 2017 and 2022 for each technology against its cost £/tCO_2 for each sector).

The "off-model" described here refers to a separate spreadsheet which enables the user to alter the values of model parameters and examine their effect on the abatement potential without re-running the actual model. This reduces the time required for each simulation[12].

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[10] The current building stock is that of 2006

[11] ENUSIM sectors include: mechanical engineering, vehicle engineering, non-ferrous metal, plastics, paper, food and drink, electrical engineering, iron and steel, textiles and other industries. N-DEEM sectors include: commercial offices; communication and transport; education; health; hotels and catering; government; other; retail; sports and entertainment; unclassified; warehouses (broadly non-domestic public and commercial sectors)

Additionally, for both the N-DEEM and ENUSIM off-models, results can be presented as the abatement potential for the separate DAs. In N-DEEM this is available for the different public and commercial subsectors. In the ENUSIM off-model the split by DA is available for all the subsectors as identified in ENUSIM, i.e. 21 in total.

5.2.7. CCC study to update UK MACCs for all sectors (2008)

Modelling completed for CCC in 2008 accompanied work to review MACCs for the UK economy as a whole. This is relevant because the model included the functionality to differentiate the CRC subsector and also resulted in the off-model spreadsheets discussed in the previous section. The intention of this project was to update the MACCs for the whole of the economy but no new data was available for the non-domestic i.e. commercial and public sectors which used N-DEEM.

The added functionality to create the CRC subsector enabled an estimation to be made of energy consumed in buildings within the CRC and of the split between DAs. Unfortunately this work did not set out abatement potential for the CRC subsector but did look at a more general analysis of the total technical abatement potential in the UK non-domestic sector. Low carbon supply technologies were included in the analysis e.g. microgeneration. The outputs of the model included abatement potential and cost per tCO_2 for 2012, 2017 and 2022.

5.3. Critique of Emissions Abatement Models

While the two models have received significant investment in their development and update, there are issues associated with using the models for any CRC related analysis. Some of the main issues are highlighted in the following paragraphs.

5.3.1. Applicability to expected CRC sectors

In summary, the coverage of CRC sectors by ENUSIM is poor because the main investment has been directed into CCA and EU ETS sectors; some assumptions are not supported by clear research in CRC sectors e.g. market penetration; and some important technologies are ignored (e.g. boilers).

ENUSIM covers industrial energy use, concentrating on the processes with the heaviest energy use and therefore the sectors which are mostly covered by the EU ETS and CCAs[13]. These emissions are specifically excluded from the CRC. The less energy intensive industrial sectors and the more minor energy using processes are not well covered in ENUSIM and none of the updates to

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[12] A drawback to this functionality is that the results are not exactly the same as the result provided by a full model run. This is because the off-models have taken a set of outputs from the actual models and have parameterised them. This means the off-models try to separate out the effects of e.g. penetration rate etc. so the off-model interpolates between real outputs of the actual model. The N-DEEM version used in this study can be considered as an off-model.

[13] ENUSIM sectors include: mechanical engineering, vehicle engineering, non-ferrous metal, plastics, paper, food and drink, electrical engineering, iron and steel, textiles and other industries

ENUSIM have tried to address the relevant CRC sectors. The technologies contained in ENUSIM which are of most relevance to the CRC are likely to be those which generate energy savings from offices, warehouses, etc., rather than from industrial process.

In summary for N-DEEM, the sectoral split is poor in relation to CRC; specialised technologies e.g. computer centres, hospitals, MOD are not researched; the basic data used seems relatively old and is based on a small sample size; all of the possible carbon savings technologies that could be applied by CRC participants are not included in either ENUSIM or N-DEEM.

While at first glance the N-DEEM sector list[14] looks useful for modelling of CRC sectors, the same technologies are applied across the different sectors. This means that the model does not accurately represent the abatement available through sector specific energy saving technologies. For example the same technologies are analysed in sectors such as offices, hospitals and supermarkets even though these sectors have widely varying requirements for energy. As described in section 5.2.7 N-DEEM was previously used to analyse the potential CRC coverage of emissions. This was however a high-level analysis and did not enable specific consideration of the public, service and industrial sectors and subsectors or the associated abatement potential.

5.3.2. Insufficient granularity of coverage

N-DEEM does not provide a sufficient level of disaggregation to identify specific subsectors within the public, commercial and industrial sectors which are key to this project. This is because:

1) The basic data is based on building type not sector characteristics; this is a problem in the many cases in which a specific type of building cannot be mapped to a specific subsector (e.g. office buildings are used in different public and commercial subsectors);
2) Some types of buildings are not included in the N-DEEM dataset (e.g. data centres) or are based on a very small sample size which may result in a biased representation of the whole group of buildings.

As a result of the two points above, there is considerable risk of misrepresentation of subsectors if data is disaggregated beyond the commercial and public level aggregation of data[15].

5.3.3. Inaccurate applicability or missing technologies for CRC sectors

The selection of technologies included in ENUSIM is not well suited to CRC sectors (see also section 5.3.1). ENUSIM is a demand use model and therefore does not include low carbon energy

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[14] N-DEEM sectors include: commercial offices; communication and transport; education; health; hospitality; government; retail; warehouses; other
[15] BRE 2010

supply technologies such as CHP, although it does model improvements in the use of steam. Energy efficiency supply measures such as for boiler efficiency are also not included. These could represent a big opportunity for CRC organisations. However, there is no recent modelling available for use in this project on boiler improvements applicable to the CRC sectors.

Until the 2007-08 update, N-DEEM included energy efficiency end-use measures in buildings such as fluorescent and LED lighting, light detectors, timers, efficient monitors, etc. but, unlike ENUSIM, also included energy efficient supply measures such as condensing boilers and boilers redesign. In 2008 some renewable (microgeneration) were added: these are photovoltaic panels, ground source heat pumps, micro CHP and solar-water heating. However, energy efficiency measures are included but not differently applied across different types of buildings. The applicability of N-DEEM for assessing coverage by the CRC is limited due to insufficient information on the split of energy and carbon abatement potential between sectors.

5.3.4. Vintage and patchy datasets

ENUSIM was established in the mid 1990s. The underlying data in the version of N-DEEM used here is from the beginning of this decade. They have been updated, see section 5.2.3, but at any time some parts of the datasets will be more current for some sectors and technologies than for others. Updates to both have not dealt specifically with CRC sectors and applicable technologies.

The ENUSIM updates have been done largely in consultation with industry sector associations and with industry sector experts from within AEAT and Ecofys. Often the data from the sector associations have been based on a small number of the larger companies. In the absence of market-based data, some data points in ENUSIM are based on expert judgement. For example most of the data on the penetration curves for technologies in the base year is either based on information from the sector associations or on the information in Enviros (2005)[16] supplemented by expert opinion. It is international common practice to develop penetration rates on the basis of expert judgements. While it would be expected that these values would correlate to actual performance of measures/ sectors, the potential for a discrepancy exists.

The Non domestic MACC (from N-DEEM) used in this study is based on outputs from a previous cost abatement analysis carried out in 2002 for the Global Atmosphere Division, DEFRA. The analysis required a number of inputs from other data sources which in turn were based on a relatively small sample (700) given the large number of different building types, uses, and occupancy patterns. Further, the data used by N-DEEM on energy efficiency technologies in buildings covers only part of the different types of buildings. Hence, differences in the portfolio of usage of technologies in different types of buildings are not accounted for.

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[16] Energy Efficiency Innovation Review (2005)

5.3.5. Lack of a temporal dimension

A marginal abatement curve does not have a temporal dimension and only gives the remaining potential at that year. The S-curves within ENUSIM give a time period under which it is expected that technologies will reach their potential but that is under a business as usual scenario and there is no evidence on which to base estimates under a policy such as the CRC. This is unhelpful from the perspective of justifying cap levels in a given year.

In both ENUSIM and N-DEEM it is not possible to predict the time period over which the technology gap can be closed which is also unhelpful from the perspective of justifying cap levels in a given year.

5.4. Existing Estimates of CRC Coverage and Carbon Savings

5.4.1. Key differences across the existing studies

This section outlines the existing estimates of CRC coverage and carbon savings and explains qualitatively the differences between these estimates including the assumptions, data and models on which the estimates are based. This section uses 'coverage' to mean the volume of CO2 that is expected to be covered by the CRC in a specific year or by year.

What really matters when considering the differences across the existing studies are the following, each are discussed in more detail in subsequent sections:

- it is not possible to compare 'like with like' (see the next points) and there is a lack of transparency around the techniques and tools used to calculate the estimates;
- CRC threshold, policy start date and rules used vary with estimates;
- carbon savings associated with other policies are variously included or excluded from the carbon saving estimates;
- estimates are made using variations of ENUSIM and N-DEEM including off-models which means not all estimates contain the same energy savings technologies;
- other assumptions which provide the inputs to estimate modelling vary with each estimate e.g. energy price values.

The scope of this work and resources available for the project did not permit a quantitative analysis of the impacts of each of these on resulting coverage and carbon savings estimates. Appendix Bdetails the assumptions e.g. fuel price, carbon price, discount rate etc., behind each of the estimates.

5.4.2. CRC coverage estimates

In the reports reviewed, the terms ‘baseline’ and ‘coverage’ are used interchangeably to refer to the size of the CRC sector.

Annual CRC coverage estimates for the 6,000MWh inclusion threshold range from 51.3 (DEFRA IA 2007) to 57.5 $MtCO_2$ (EA 2009). For the 3,000 MWh inclusion threshold the estimates are 55 $MtCO_2$ (Enviros/ NERA 2006). DEFRA were unable to confirm why the 2007 IA coverage estimate is considerably lower than that for the Partial IA in 2009.

Estimates of carbon coverage have decreased as the CRC policy has been developed[17], with the exception of EA 2009 which identified higher coverage.

[17] There has been inconsistency in the units in which coverage estimates have been reported (some studies use tonnes of carbon whilst others use tonnes of CO_2). In this report all MtC figures have been converted to MtCO2 and included in Table 5.

- **Table 5 Existing CRC coverage estimates by study**

Study number	Study	Coverage estimate per year (MtCO2)	Threshold (MWh)
5	Enviros/ NERA 2006	Estimated for 2010 65 55 46	 zero 3,000 10,000
6	DEFRA First consultation 2006	55	3,000
7	DEFRA IA consulting on options 2007	55	3,000
		51.3[18]	6,000
8	CCC Review and update 2008[19]	54.52	3,000
		52.06	6,000
9	DEFRA Partial IA 2009	53.2	6,000
13	DECC Final IA 2009	53.2	6,000
14	EA 2009	57.5 in 2008	6,000

Note: Enviros/ NERA 2006 estimate for a zero threshold implies SMEs have not been excluded. Source: SKM Enviros, Ecofys, Entec UK (2010)

5.4.3. Carbon savings estimates

To date several types of CRC carbon savings estimates have been provided. These are outlined below.

- Annual cost effective carbon savings in or by a given year. Cost effective is defined as abatement potential delivered at £0 /tCO_2. For 2015 carbon savings range from 2.2 (Enviros/ NERA 2006) to 1.3 MtCO_2 (DECC Final IA 2009). For 2020, these range from 4.8 (Enviros/ NERA 2006) to 3.2 MtCO_2 (DECC Final IA 2009). The EA (2009) suggested a saving potential 9.2 MtCO_2 but did not specify the year.
- Total abatement potential (or technical potential) from a given year. This ranges from 12.1 MtCO_2 in 2010 (Enviros, NERA 2006) to over 16 MtCO_2 in 2012 (EA 2009). Most studies reviewed did not provide an estimate of the total abatement potential.
- Cost effective abatement potential aggregated over a number of years: estimates provided range from 7.9 MtCO_2 over a five year period after the exclusion of CCA, EU ETS and other policies (Enviros/ NERA 2006) to 11.6 MtCO_2 by 2020 (EA 2009).

See Appendix B for the table summary of the carbon savings estimates. Estimates of carbon savings have decreased as the policy has been developed, with the exception of EA 2009. This will be discussed in more detail in the next section.

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[18] Lower coverage estimate could not be explained by DECC contact

[19] On p19 the report states total coverage is 54.5 MtCO2 of which 29.15 MtCO2 is industry and 25.3 MtCO2 from commercial and services sectors

5.4.4. Comparing estimates

The Enviros/ NERA 2006 work provided the basis for CRC coverage and carbon savings estimates for the series of DEFRA/ DECC IAs (2006, 2007 and 2009 (both)) and the Low Carbon Transition Plan (2009). Various adjustments were made to each subsequent estimate around inclusion or exclusion of carbon savings from other policies and to take into consideration the change in threshold and policy start dates. The Enviros/ NERA 2006 work was also used in the CCC Review and update (2008) and EA (2009) with other differences. Consequently CRC coverage and carbon savings estimates cannot be compared 'like with like'.

5.4.5. CRC threshold, policy start date and rules

A higher Half-Hourly Meter (HHM) threshold and later policy start date creates a smaller pool of CRC emissions i.e. coverage and therefore reduced abatement opportunities which give the carbon savings by a certain year.

The Enviros/ NERA (2006) study estimated 4.8 $MtCO_2$ cost effective carbon savings in 2020 but this potential was estimated on the basis of a 3,000 MWh/ year HHM threshold and the scheme starting in 2008. In comparison, the DECC Final IA (2009) estimated carbon savings in 2020 to be 3.2 $MtCO_2$ on the basis of a 6,000 MWh/ year threshold and the scheme starting in 2010.

The CRC coverage and savings estimates will also be affected by the volume of emissions the sectors are responsible for as a whole and the projected energy use profiles for the sectors over time. The size of the sectors is discussed in more detail in section 7.

Policy changes e.g. around inclusion of schools, all central government departments etc., are variously accommodated by modelling and estimates, and there has been no revision to CRC sectoral estimates to reflect policy changes up to now. For more detail on the policy changes see section 5.

5.4.6. Carbon savings associated with other policies

The studies do not always make explicit how carbon savings associated with other policies have been accommodated in the estimates.

Enviros/ NERA (2006) excluded all sites with CCAs from the analysis but used the lower threshold of 3,000MWh/ year. Carbon savings in 2020 are estimated as 3.6 $MtCO_2$ (DECC Partial IA 2009) which includes 0.4 $MtCO_2$ overlap with smart meters and Energy Performance of Buildings Directive (EPBD), and 0.4 $MtCO_2$ delivered from purchases of EUAs but excludes 0.4 MtCO2 delivered through another part of the EPBD. The DECC Final IA (DECC October 2009) revised this estimate down further to 3.2 $MtCO_2$ by excluding the savings from the purchase of EUAs.

5.4.7. Energy saving technologies

Carbon savings estimates are in part determined by the factors above and the nature and completeness of carbon saving technologies included in the analysis[20]: sectoral technology 'relevance', the starting point for market penetration, rate of uptake, acceptable payback/ rate of return and market barriers[21].

Estimates of carbon savings and abatement potential cannot be compared 'like for like'. Although all are based on ENUSIM and N-DEEM modelling, these models have been updated at different points since the Enviros/ NERA 2006 work, see section 5.2.3, e.g. to include low carbon energy supply measures in N-DEEM in 2007-08. As noted previously, the models are not specifically tailored to the CRC sectors either in the sectors they cover or in the relevant carbon and energy saving technologies for the CRC sectors. Also, since ENUSIM and N-DEEM are difficult to re-run off-model adjustments have been necessary to enable their use which generates differences in carbon savings estimates.

5.4.8. Other assumptions

Assumptions which impact on CRC coverage and carbon savings estimates include the policy threshold, start date and savings associated with other policies e.g. smart metering or EPBD - all of which are discussed above. Also impacting on estimates are the emissions factors, carbon price, discount rate and fuel price assumptions.

Energy price assumptions are not consistent across the estimates, see Appendix B. The effects of higher energy prices on abatement levels were not re-modelled at each major IA stage – instead off-model adjustments were made to Enviros/ NERA (2006) work to provide revised figures provided in the IAs. The impact of the different energy prices used in the later estimates must be considered against, for example the higher policy threshold and start date used, to explain the lower carbon savings estimates provided by the later IAs. DECC notes that higher energy prices used in the Partial IA in 2009 drives more abatement than in the 2007 IA but this impact is negated through using the 2010 start date (instead of 2009) in 2007 IA. Further discussion around fuel prices and the impact on the EA 2009 savings estimates is in the following section.

5.4.9. EA 2009: an outlying estimate

As seen above, the EA 2009 estimates of CRC coverage and particularly of carbon savings are much greater compared to the DECC IAs.

[20] See section 5.3.3
[21] See section 11.4

The EA work is based on ENUSIM and N-DEEM as are the DECC IAs and Enviros/ NERA 2006 estimates. It has not been possible within the scope and resources of this project to conduct sensitivity analysis on any of the estimates. A qualitative comparison of the key differences between the coverage and carbon savings estimates from the EA 2009 study and the DECC IAs and Enviros/ NERA 2006 studies is provided below[22]. The EA 2009 estimates:

1) Were based on recent updates to the emissions data available for the water and public sectors including the aggregation of emissions from state schools to their local authority and a different consideration of the 'Other industries' sector.
2) Used lower fuel prices (pre-recessional UEP): CCC 2008 work used 2007 fuel prices which were peaking – higher prices stimulate greater uptake of energy efficiency measures. By 2009, fuel prices used in modelling were much lower. As explained previously, the MACCs are based on the difference between uptake under BAU and total potential. With lower prices the uptake is lower and therefore there is a greater potential remaining at a given year;
3) Used different economic growth forecasts to the two studies (Industry IOP growth forecasts published by DECC). A higher growth scenario would result in more emissions in the target year and therefore higher absolute emissions savings (although in the modelling the relative savings for a particular sector is not affected by the growth assumptions);
4) Corrected an error in the ENUSIM calculation of carbon emissions which resulted in their higher estimation compared to previous studies;
5) Used a 2008 baseline for scheme emissions (Enviros/ NERA 2006 was set against 2005).

Points 2 to 4 are likely to be the main reasons for the considerably higher volume of carbon savings estimated for the CRC by EA 2009.

The outputs of this work were: an overview of how caps might be set for the CRC sectors, what level they may take and what the implications of the caps may be. MACCs were also calculated, referring to the marginal cost (in £/ tCO2 saved or £/ unit of energy saved) to private investors of implementing measures to reduce energy consumption/ emissions. This was set within the context of the CCC's report to government on the three carbon budgets to 2022 and the compilation of a plan to meet those budgets.

5.5. Low Carbon Generation

The size of the cap for the first fixed phase of the CRC will depend in part on the carbon saving potential available to CRC participants from renewable technologies and other low carbon supply measures. CRC rules[23] require CRC allowances to be bought for electricity used by an organisation

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[22] AEAT pers comm. (2010)
[23] Taken from the January 2010 version of the CRC User Guide and set out in The CRC Energy Efficiency Scheme Order 2010

which was generated from renewable sources where ROCs or FITS are claimed. This is because the emphasis of the CRC is on energy efficiency improvements rather than providing further incentives for renewable energy generation.

The measures that can be used by CRC participants to save carbon include:

- energy efficiency measures in end use e.g. heating control;
- energy efficiency measures on local energy supply system e.g. boiler efficiency;
- low carbon energy supply e.g. fuel switching (oil to gas; electric to gas), renewable electricity (if ROCs or FITs are not claimed), renewable heat, CHP, heat pumps.

5.5.1. Existing estimates

The carbon savings estimates already discussed in this section variously include and exclude abatement potential available from different types of energy and carbon saving technologies, see below and section 5.3.3.

- ENUSIM includes end use energy efficiency measures but not supply measures.
- N-DEEM originally included end use energy efficiency measures but not supply measures. In 2007-08 low carbon supply e.g. renewable electricity measures were added. Generally savings from renewables are included separately in the studies.
- Enviros/ NERA 2006 and the DECC IAs were based on ENUSIM and N-DEEM so have not included supply side measures.
- Several studies have incorporated certain types of low carbon supply measures as off-model adjustments. For example, the CCC Review and Update 2008 (based on ENUSIM and N-DEEM) incorporated CHP, solar water heating, heat pumps and PV. EA 2009 work incorporated fuel switch.

5.5.2. Incorporating low carbon supply into new estimates

Several of the studies listed in section 5.1 discuss and model carbon savings potential from renewable heat (see Appendix C) and electricity[24]. These are considered in more detail where relevant in section 8 in the context of developing new modelling for this CRC cap setting analysis.

There are limitations associated with using these data sources for CRC-related analysis, outlined below. Overcoming the limitations and using the relevant information is discussed in section 8.

[24] DECC 2009b: the analysis of the options for designing a Feed-In Tariff for Great Britain models uptake of each renewable technology under a wide range of feed-in tariff designs built up with renewable energy supply curves, showing the size of the resource available at a given generation cost.

The CCC Heat model (2009) does not provide an exact overlap to organisations covered by the CRC although it is divided into the commercial, industrial and public sectors. The DECC RH supply curve 2009 work does not break the uptake of heat technologies down by individual sectors although again CRC sectors are covered through large and small installations in the commercial, public and industrial sectors.

DECC (July 2009a) RH supply curve work assumes the EU ETS covers 2 MtCO2 of emissions from large public and commercial segments. Previous mappings of renewable heat and the EU ETS have not included the commercial sector.

The CCC Heat model (2009) does not include renewable CHP technology. The FITs work (DECC Design of FITS 2009) was not developed in the context of the CRC and does not allow the amount of savings between the FITs and the CRC to be separated because the background study of FITs was based on national figures and there is not enough information to be able to extract the data on non-domestic CRC buildings.

5.6. Concluding Comments on Previous Models and Studies

This section answers the questions set in section 5.1 and draws conclusions on the implications for CRC cap-setting.

5.6.1. Approaches

The ENUSIM and N-DEEM bottom-up energy demand models coupled with Enviros/ NERA (2006) provide the anchor points for all subsequent work and CRC coverage and carbon savings estimates. There have been several off-model adjustments e.g. CCC Review and update (2008) and updates to the models. ENUSIM and N-DEEM however remain as the basis for carbon savings and sector information with Enviros/ NERA 2006 defining the relevant sectors.

5.6.2. Outputs

ENUSIM projects energy use in a sector taking into account uptake of cost effective abatement technologies and can provide technology-by-technology MACCs at given years. N-DEEM can provide MACCs that identify the potential reduction in absolute carbon emissions and cost per tonne for a range of technologies applied to UK non-domestic public and commercial sectors. Together these have been used to provide a series of CRC coverage and carbon savings estimates that vary chronologically as assumptions, changing policy features and updates to the models have been accommodated. Examples of assumption variation across estimates are given below.

- Different energy price assumptions are used across the studies (see section 5.4.8 and Appendix B) and emissions savings attributable to other policies are variously included and excluded in the CRC carbon savings estimates. Therefore estimates of savings and coverage vary.
- There has been no revision to CRC sectoral estimates to reflect policy changes. Enviros/ NERA (2006) used the 3,000 MWh threshold for analysis and information on sector coverage and has since been used as the basis of analysis on the CRC with the 6,000 MWh threshold. For example, the EA 2009 study estimates carbon savings by 2022 of 11.6 MtCO2 based on the Enviros/ NERA 2006 coverage estimate of 55 MtCO2 for a threshold of 3,000 MWh rather than the EA's revised coverage estimate of 57.5 MtCO2. This was because there was a lack of faith in the revised estimate.

There is uncertainty over the number of organisations that may be excluded from the CRC due to the unknown results of the exemption for those organisations with more than 25% of emissions covered by a CCA[25]. The Enviros/ NERA 2006 report only excluded CCA energy rather than potentially whole organisations - the '25% rule' did not exist in 2006. This could be important – the CRC coverage shown in 2006 report for CCA sectors is likely to be too high.

5.6.3. Limitations

The models have several limitations for CRC cap setting analysis, see section 5.3. Combining these with how the models have been used to generate CRC coverage and carbon savings estimates, it is clear that estimates cannot be compared 'like with like', and are of questionable accuracy. The model limitations for cap setting are summarised below.

- ENUSIM and N-DEEM datasets are not designed for CRC sectors, in terms of how the sectors are disaggregated, which sectors are included and the carbon savings technologies and savings attributed.
- Any new estimates generated using ENUSIM and N-DEEM would be based on old datasets.
- It is not possible to predict the time period over which technology uptake will develop in either ENUSIM or N-DEEM.
- Due to the series of updates, outputs from these models used as inputs in subsequent studies will have changed. In addition, not all areas of both models have been updated.

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[25] CCA 25% rule: if a single organisation has a CCA that covers over 25% of its relevant emissions it will be fully exempt from CRC for that phase. If a member of an organisational group has more than 25% of its CRC emissions covered by a CCA, that member is exempt from CRC.

6. CRC cap setting requirements

6.1. Introduction

This section provides a link between the review of existing work in section 4 and the modelling of the CRC cap. It is intended to provide an evaluation of some of the key requirements for accurate cap setting and it sets the scene for the subsequent sections which detail our modelling assumptions and the required amendments to ENUSIM and N-DEEM outputs.

Accurate cap setting is a vital element of the success of the CRC policy. Historical experience in both the UK ETS and EU ETS illustrates that carbon trading markets can fail to deliver emission reductions if a cap is set too generously[26]. There are also concerns that if a cap is set too tightly that the CRC policy will create significant financial difficulties for participants.

The CRC cap will define the annual quantity of CO_2 that can be emitted by all CRC participants in a given year. The cap is established by estimating the abatement potential available to participants in a given year and subtracting that amount from a "baseline" emission that represents the emissions at the start of the CRC scheme. From a modelling perspective this means we need:

a) An accurate baseline (or base year) of emissions for the actual group of participating organisations in the CRC.

b) An accurate assessment of projected emissions out to 2022 under business as usual (BAU).

c) An assessment of what is being delivered by other policies.

d) An assessment of the overall potential to reduce emissions from this group of organisations.

e) An assessment of the rate of achieving this abatement potential, to allow annual caps to be set.

It is important that each of these elements is in place before the cap is set. Details about each of these requirements are discussed in this section. This section of the report is structured as follows:

- section 6.2 outlines the nature of the CRC baseline and sector understanding required for accurate cap modelling;
- section 6.3 outlines the abatement potential modelling required, including a discussion about MACCs, existing market penetration and temporal effects;

[26] Driesen (2010)

- section 6.4 discusses the way that different types of Government policy must be taken into account when setting the cap.

6.2. Baseline CRC Coverage and Sector Analysis

6.2.1. What is needed

The cap is set by subtracting an estimate of abatement potential from the level of emissions at a certain year in the future (projected from a baseline or base year emission under BAU). Hence an accurate baseline or base year and an understanding of projected emissions under BAU is crucial. A good understanding of the split of the baseline into different end use sectors is also crucial as any modelling of abatement potential must be done on a sector by sector basis.

An accurate baseline also needs to be of sufficient granularity within certain large sectors to represent the heterogeneity of energy use and carbon savings across a sector. For example, it is not adequate to assess the baseline for a large sector such as retail because the sector includes widely differing types of operation such as supermarkets, department stores and small shops. Accurate modelling of abatement potential for large sectors like retail needs to be done at a "subsector" level – and the baseline data must also be available at that level of detail.

Baseline coverage must be split into current levels of electricity and heat usage as this is a vital input to modelling of energy saving potential. Baseline CRC coverage must also incorporate the current policy features, e.g. 6,000 MWh threshold, CCA exemptions and 2010 start date, and a good understanding of how the sectors might be grouped for modelling purposes going forward.

6.2.2. What is currently available

The review of existing work suggests that previous estimates of baseline coverage are not accurate enough for cap setting for several reasons. There is not enough good data about organisations above and below the 6,000 MWh eligibility threshold. Previous estimates have not properly taken into account the various CRC rule changes that have occurred as the CRC policy has developed. For example, most of the industry sector coverage estimates in the reports reviewed use exactly the same figures as estimated in Enviros/NERA 2006 even though those estimates were made before the "CCA 25% rule" was introduced. The previous sectoral analysis seems to over-estimate the industrial coverage and under-estimate public and commercial sector non-domestic buildings. Previous estimates do not provide sufficient granularity in certain large sectors such as retail, hospitality and the public sector.

6.2.3. New estimates provided in this project

We have tried to provide an improved description of the sectors and sub-sectors that will provide sufficient granularity for future cap setting analysis. We have also provided updated estimates of baseline coverage, but do not expect that these are accurate enough for actual cap setting. The results of this work are described in section 7. We do not recommend that CCC uses these baseline emissions numbers to derive an accurate CRC cap. They can be used to estimate an approximate cap and for scenario modelling. The revised list of CRC sectors and subsectors should be used as the basis for future CRC cap modelling activity.

6.2.4. Other comments about baselines

The baseline used for cap calculations may need to be adjusted over time to take into account "structural changes" in the CRC e.g. new entrants and exits.

Other adjustments that must be made to the baseline include the impact of economic and population growth (which historically have tended to increase energy consumption).

The baseline estimated in section 7 is based on DUKES data for 2008. Given that DUKES itself includes various modelling assumptions[27] and that the CRC baseline estimate needs assumptions to be made about coverage (especially those related to the 6,000 MWh threshold and the CCA 25% exclusion rule) there is little benefit in adjusting this estimated baseline to provide a figure for 2010 or 2011. The baseline will only be known accurately enough after real CRC footprint data is available after the first and second years of the CRC introductory phase.

6.3. Abatement Potential Prediction Tools

6.3.1. What is needed

A set of prediction tools is required for CRC cap assessment which enables the accurate modelling of the potential for CO_2 emission reductions for all CRC participants. The start point should be an accurate baseline, which can be established from real data as described in section 5.2 above. The tools must then be able to:

- **Provide an accurate assessment of total emission reduction potential in each sector or sub-sector**. This will most accurately be done by making separate estimates for electricity and heat savings. The model for each sector or sub-sector must accurately reflect the different types of energy use expected. The models should also be based on realistic estimates of the current penetration of each energy-saving technology.
- **Evaluate the savings as a "time series" over the period for which annual targets are required**. The total technical potential for carbon savings does not establish a cap in a given year. The model needs to distinguish between savings that can be achieved quite quickly and savings that are more likely to occur over a longer time period.

[27] It has not been possible to ascertain these for this study

- **Take into account influencing factors**. This should include energy prices, price of carbon, and interest rates.
- **Be flexible enough to evaluate different groups of savings**. There are a number of important sub-groups of savings, including end use energy efficiency, on-site energy supply system efficiency, on-site renewable electricity and heat supply and decarbonised grid electricity supply. The modelling needs to evaluate some of these separately so that cap assessments can be flexible to future government policy.
- **Be flexible enough to take into account technology change**. The availability of cost effective technologies to reduce emissions is likely to change rapidly over the next few years. Future cap assessments need to account for the possibility of new technologies becoming available and cost effective.

6.3.2. What is currently available

The current modelling tools do not enable the accurate estimate of a cap for the CRC. The ENUSIM and N-DEEM models as discussed in section 5.2 were not designed to meet all the needs described in above. They have not been updated to model the CRC sectors and relevant energy saving opportunities. The models do not provide a good basis for a "time series" analysis that is vital for an annual cap setting process.

6.3.3. New work carried out in this project

Modelling for this project goes some way towards supplying what is needed for cap assessment. The modelling is described in sections 8 and 9. It provides a framework with the flexibility to meet some of the requirements described above. For example the model can make use of accurate baseline data for each sector as it become available and allows the user to vary a wide range of influencing parameters such as price of CO_2, fuel prices, discount rates etc.

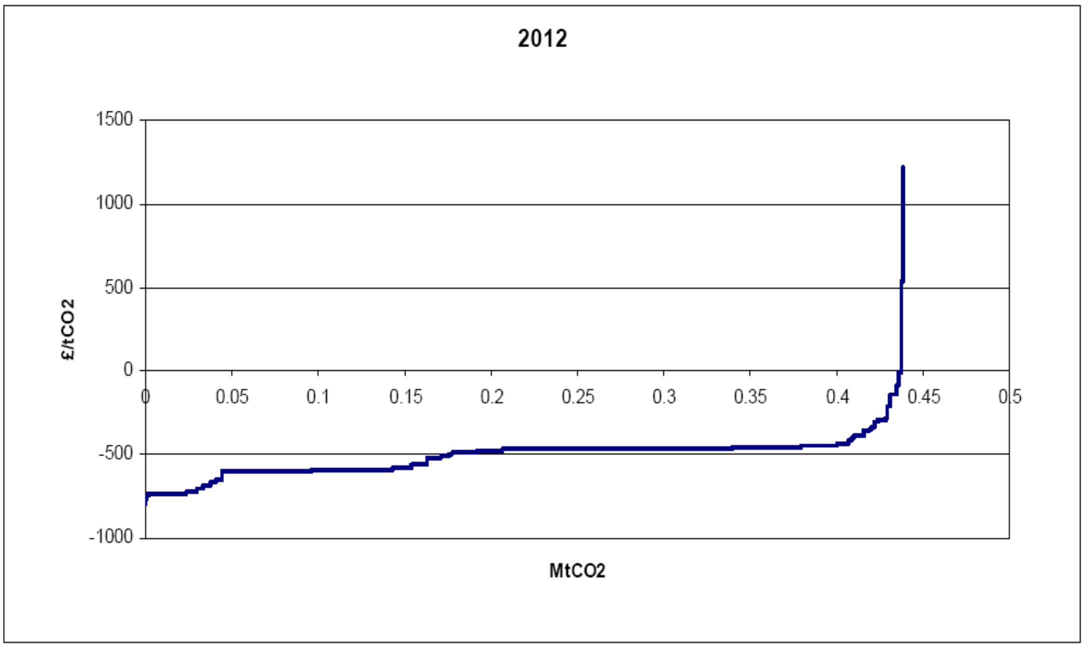
However, it must be recognised that within the scope and timeframe of this project it has only been possible to use MACCs from the existing ENUSIM and N-DEEM models, despite the noted shortcomings. Some improvements to the modelling have been carried out (see section 8 and section 9) but these do not overcome the fundamental weaknesses of the existing models.

6.4. Comments on Marginal Abatement Cost Curves (MACCs)

The MACCs currently generated from ENUSIM and N-DEEM have shortcomings in respect of analysing CRC sector abatement potential, as described in section 5.3.

Figure 1 shows a copy of the ENUSIM derived MACC for the mechanical engineering sector from the EA 2009 report. This MACC for mechanical engineering illustrates the difficulty in using a bottom-up model like ENUSIM to assess the sensitivity of the cap to key economic drivers such as carbon and fuel prices.

Figure 1 ENUSIM MACC for Mechanical Engineering from EA 2009 Report



The curve rises almost vertically from a CO_2 price of less than £0/tCO_2. This implies that there are no cost effective technical measures that can be implemented with the stimulus of a CO_2 price in the range of, say, £0/ tCO_2 to £100/ tCO_2. All of the available measures are cost effective with a low CO_2 price (and also with a low fuel price). This is counter intuitive and is not representative of the real world – one would expect a range of energy efficiency measures to become cost effective as the CO_2 price rises towards £100/ tCO_2. What the MACC actually illustrates is that the "menu" of bottom up measures used in the ENUSIM model is not sufficiently comprehensive to allow for the uptake of measures that have lower cost effectiveness.

Another difficulty of using a MACC like that shown in Figure 1 is that it only represents a sub-set of all the available technology options. For example it does not include options such as CHP, renewable energy and grid decarbonisation. There are a few measures in the ENUSIM models that show potential for efficiency improvements at costs well in excess of £1000/tCO_2. These measures should be screened out of the MACC as it would clearly be cheaper to use various energy supply options such as CHP or renewables that are expected to be cost effective at much lower CO_2 prices.

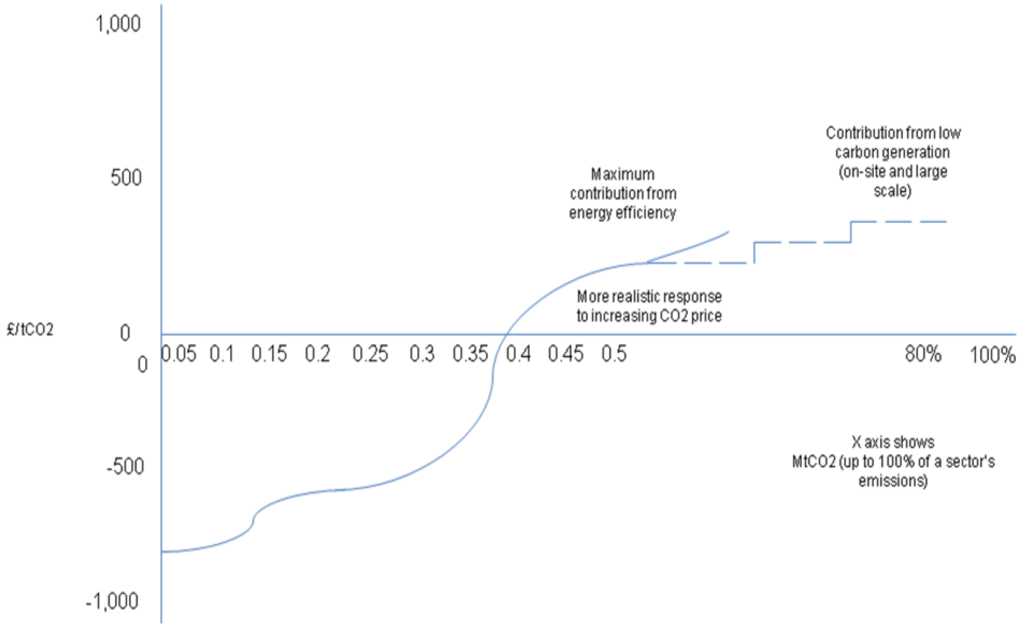
The MACC in Figure 1shows an overall potential for just over 0.4 $MtCO_2$. However, it does not give any indication of what proportion of the total mechanical sector emissions can be saved. This would be helpful, especially bearing in mind the challenging UK targets for 2050.

An improved MACC would have the following characteristics:

- The x-axis of the curve should be scaled to 100% of the sector emissions because the abatement opportunities should cover the whole of the sector's emissions.
- The energy efficiency measure analysis would be more comprehensive so that it would show the expected savings that can be achieved in the £0/ tCO_2 to £100/ tCO_2 range.
- The curve should include an indication of the cost effectiveness of both on-site and off-site low carbon energy supply options that could "plug the gap" between energy efficiency savings and the long term target of 80% emissions reduction.

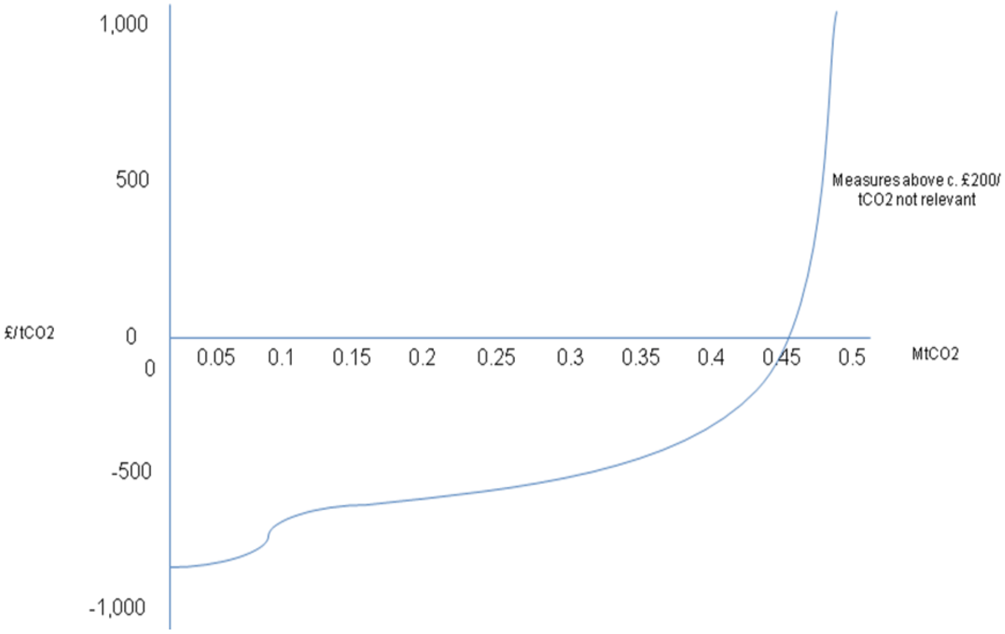
A MACC with these characteristics is shown in Figure 2 in comparison to an example of a traditional MACC for a CRC sector (Figure 3).

- **Figure 2 Hypothetical MACC for a CRC Sector**



Source: SKM Enviros, Ecofys, Entec UK (2010)

- **Figure 3 Traditional MACC example for a CRC sector**



Source: SKM Enviros, Ecofys, Entec UK (2010)

6.5. Comments on Temporal Effects

MACCs are a useful way of illustrating overall abatement potential but they do not provide the information required to judge the rate of uptake of the various abatement technologies. There are many factors that affect the rate of uptake of individual emission reduction projects such as:

- cost effectiveness.
- availability of capital (in absolute terms and relative to competing demands for capital).
- availability of resources to identify and implement projects.
- equipment / building replacement cycles.
- project risk (e.g. new / unproven technology or a project reliant on a certain fuel price scenario).
- strength of legislative and other external drivers (e.g. reputational drivers).

To address some of these points it is helpful to segregate abatement projects into a number of groups – each of these groups will be affected by the above factors in different ways. Four logical groups for CRC participants are:

1) **Very cost effective projects requiring limited capital.** Typically these will have a payback period of less than 2 years. Most CRC organisations will have few competing projects with better financial characteristics, so these projects are "no brainers". The main barrier is a lack of awareness and lack of resource for implementation. Given the extra leverage created by the CRC itself one would expect all such measures to be taken up quite quickly e.g. within 3 to 4 years.
2) **Cost effective retrofit projects.** These might have payback periods in the 1 to 4 year range and may require a significant capital investment and a sophisticated planning / implementation methodology. The projects might be equal in financial performance to other business opportunities and hence will need to compete for capital. It remains good sense to carry out such projects, but the implementation cycle across the whole CRC will be slower e.g. 8 to 10 years. It is worth noting that the cost effectiveness of such projects will be affected by the price of CO_2 – CRC participants will be more motivated to implement these as the price of CO_2 rises.
3) **Equipment replacement projects, short cycle.** These are projects that only become cost effective when an old piece of equipment reaches the end of its life and is due for replacement. At that time there is a "once in a lifetime" opportunity to ensure the purchase of a more efficient piece of equipment. For some types of equipment e.g. office systems such as computers and printers the normal lifecycle is relatively short e.g. 10 years.
4) **Equipment replacement projects, long cycle.** These are projects similar to (3) above but they occur much less frequently. For example replacement of major industrial process systems (e.g. baking ovens) or building infrastructure (e.g. air-conditioning systems). This group can also include opportunities that occur on a completely new building or industrial process. Typical cycles for such investments are between 25 and 40 years. Whilst these will have relatively little impact on the CRC cap to 2017 the full uptake of such opportunities is vital in terms of meeting 2050 targets.

The modelling work described in sections 8 and 9 take these four groups into account, but there is a lack of suitable information in the ENUSIM and N-DEEM outputs to make full use of the groupings.

6.6. Overlaps Between CRC and Other Policies

The cap assessment must take into account the impacts of a range of different policies in addition to the CRC itself. The emissions from CRC participants will change in a number of ways over the life of the CRC, for example due to:

- economic and population growth;
- BAU investments in energy efficiency measures;
- implementation of efficiency measures leveraged through other Government policies e.g. Building Regulations;
- implementation of renewables measures leveraged through other policies e.g. R.O. and FITs.
- the impact of the CRC itself.

All of these drivers will cause the emissions to change from the baseline figure. The modelling carried out with tools such as ENSUIM and N-DEEM represent the total technical abatement potential. The tools are not policy specific. The cap must be based on the overall cost effective technical abatement potential in a given year not just the incremental reductions achieved by the CRC policy itself. See section 10.5.3for further discussion of this issue.

An important consideration for CCC and DECC is the way in which carbon conversion factors for different fuel types are taken into account. Two important examples are:

1) Treatment of on-site renewable electricity projects. If these are implemented without other incentives (such as ROCs or FITs) then they ought to be zero carbon rated, but if the incentives are used, the current intention is to use grid average carbon. Hence the actual CO_2 emissions from a site and the "CRC emissions" may be different. The cap calculation must take this into account.
2) Treatment of grid decarbonisation. Through the RO, FITs and other polices, we expect average grid carbon factors to change over the life of the CRC. The cap can either be calculated using fixed grid factors, fixed factors within a CRC phase or annually varying factors.

6.7. Conclusions

This section has described the baseline data and prediction tool requirements for CRC cap setting assessments. It highlights how modelling for this project has been designed to fulfil some of the requirements. Section 8 provides an introduction to the modelling approach taken for this project. However, it is vital to note that we do not believe it is possible to overcome the inadequacies of the ENUSIM and N-DEEM models in relation to the CRC without a major rethink of the modelling strategy. Recommendations for modelling next steps are outlined in section 12.

7. CRC sectors and baseline coverage

7.1. Introduction

Understanding the sectors and subsectors that will be represented in the CRC is very important in relation to cap setting from 2013 onwards. The cap must be based on an accurate understanding of the relevant sectors, size of their emissions at the start of the CRC scheme and the carbon abatement potential available to each sector. This requires the application of modelling techniques to an appropriate set of sectors and subsectors.

At a high level we can split CRC participants into three main groups:

1) Public sector organisations;
2) Private sector organisations – commercial;
3) Private sector organisations – industrial.

However, modelling of abatement potential must be carried out at a more granular level of sectors and subsectors. Each chosen sector must consist of a sufficiently homogeneous group of businesses to allow reasonably accurate modelling. This section examines this issue and provides a recommended structure of sectors and subsectors that should form the basis of further modelling work. It also provides an improved estimate of the CRC coverage in each sector and sub-sector.

This section is structured as follows:

- section 7.2 reviews the previous choice of sectors covered by earlier CRC studies;
- section 7.3 outlines some important issues associated with mapping CRC participants into sectors and subsectors;
- section 7.4 recommends how CRC participants should be mapped into sectors and subsectors;
- section 7.5 gives an estimate of CRC coverage for the recommended sectors.

7.2. Sectors and Coverage in Previous Studies

Most of the previous studies used a set of sectors originally defined in the NERA / Enviros 2006 study. Table 6 shows the table from the EA 2009 study that incorporates sector coverage estimates from the 2006 study together with updated estimates made in 2009.

- **Table 6 Table from EA 2009 study showing sectors and coverage**

Subsector	NERA/Enviros Emissions Covered by CRC (tCO2/year)	EA Updated emissions covered by CRC (tCO2/year)	Updated % of total CRC coverage
Aluminium	443,018	443,018	0.77
Bricks	-	-	-
Cement and lime	-	-	-
Ceramics	521	521	0.00
Chemical	2,385,948	2,385,948	4.15
Construction	153,241	153,241	0.27
Education	380,754	380,754	0.66
Electrical Engineering	980,034	980,034	1.70
Energy	-	-	-
Food and drink	982,806	982,806	1.71
Glass	293,737	293,737	0.51
Health and social work	887,487	887,437	1.54
Hotels & Restaurants	4,425,505	4,425,505	7.70
Mechanical Engineering	2,715,310	2,715,310	4.72
Other industries	6,397,175	6,397,175	11.13
Other Non-Ferrous Metals (NI-M)	-	-	-
Paper and board	1,873,832	1,873,832	3.26
Plastics	3,876,477	3,876,477	6.74
Public administration	5,221,374	8,105,108	14.10
Real estate	1,119,100	1,119,100	1.95
Retail trade	6,631,878	6,631,878	11.54
Motor vehicles	-	-	-
Steel	5,058,493	5,058,493	8.80
Transport, storage and communication	152,629	152,629	0.27
Vehicle engineering	2,559,113	2,559,113	4.45
Water	738,855	3,431,837	5.97
Wholesale trade	4,635,202	4,635,202	8.00
Total	**51,912,487**	**57,489,203**	

Source: EA (2009)

This table illustrates several shortcomings in previous sector definitions and sector coverage estimates. In particular:

a) There was no clear structure in terms of the three high level groups described in section 7.1(for example public sectors are not separated from private sectors).

b) A number of sectors were identified but shown with zero CRC coverage, on the basis of CCA exclusion. This is unlikely to be correct given the way that separate legal entities in CRC organisations are evaluated for CCA exclusion.

c) There is insufficient granularity in some of the sectors chosen – especially those related to the public sector and private commercial sectors. For example public administration and retail are both very broad sectors covering many different types of activity.

d) For most sectors the updated 2009 coverage estimates are exactly the same as the original 2006 estimates. This cannot be correct given a number of rule changes that occurred between 2006 and 2009 (e.g. the change in CRC threshold, the introduction of the CCA 25% rule and the mandatory inclusion of schools in Local Authority portfolios).

The CCC Review and Update (2008) did not include the commercial sector, transport, vehicle engineering, water and wholesale trade but included textiles. The textiles subsector is not covered by any other study. All studies except for the CCC Review and Update (2008) included wholesale trade. Sports and entertainment does not appear to be included in any of the coverage and emissions savings estimates although we would expect some CRC coverage in these sectors.

We have taken the view that previous sector definitions and coverage estimates are not of sufficient quality for the basis of obtaining a good understanding of the CRC cap and have proposed a more robust approach described below.

7.3. Understanding Types of CRC Sector

Before defining specific sectors that are suited to the CRC it is helpful to discuss some generic issues that have shaped our thinking. A key starting point is to ensure comprehensive coverage of all sectors that might be included in the CRC. This has been achieved by making use of the Standard Industrial Classification (SIC)[28] to ensure all types of organisation that might be a CRC participant have been considered.

In addition we have identified three important issues that affect the way CRC sectors should be selected and modelled.

[28] SIC 2003

For certain **industrial subsectors** it is important to recognise the way in which CCA sectors overlap with CRC participants. Heavy industrial sectors such as steel, chemicals, food and drink have significant CCA coverage. These sectors have been well analysed in ENUSIM, as part of CCA negotiations. Many (perhaps most) companies in these sectors will be excluded via the CCA 25% rule. Relatively small parts of some companies in these sectors may remain in the CRC. However, in almost all cases the remaining company "fragments" will bear little relationship to the industry sector that the company belongs to, in terms of processes (and hence in terms of emissions reduction modelling). For example, in the steel industry it is expected that some steel makers will have a small part of their company in the CRC, but sites with steel making processes will all be excluded from the CRC due to CCA coverage. The remaining steel company "fragment" might consist of depots and offices or of some unrelated non-energy intensive industrial process. It would be wrong to try to model these fragments using the ENUSIM model for the steel sector. For this reason, we recommend grouping a number of the major industrial sectors together as a set of "industry fragments" and modelling them as a light industry/ commercial participant.

For certain **commercial subsectors** it is important to recognise that some of the subsector levels used in previous CRC modelling are too heterogeneous for accurate modelling. A good example is retail, which has previously been treated as a single subsector. The nature of different types of retail business varies enormously which makes accurate modelling of emission reduction potential for the whole group impossible. We recommend splitting such groups into a number of subsectors. For retail, this could be three groups: supermarkets, department stores/ shopping malls and small shops. The more subsectors used the more accurate the modelling can become, but for reasons of practicality and cost it is necessary to limit the number of subsectors used.

Some CRC participants will be **multi-sector organisations**. Their carbon footprint will be reported as a single set of energy use data, but the usage might span more than one of the subsectors chosen for the modelling analysis. For example, a Local Authority will report a single set of data covering offices, schools, leisure facilities and various other activities. This is heterogeneous grouping that needs to be very carefully modelled.

7.4. An Improved Set of CRC Sectors

As described in section 6.2 for accurate cap setting it will be important to establish CRC baselines from participants' actual data available from the end first year of the CRC. This will require each participant to be mapped into a relevant sector to establish sectoral baselines.

The EA will need to gather sufficient information from participants registering with CRC to allow such a mapping exercise to be carried out. This data will be at an **organisation** level. Participants will fall into three main groups:

1) Participants with a dominant activity that maps easily into one homogeneous sector. For example supermarkets. Whilst supermarkets have a varied range of activities including large head office buildings and major distribution depots, their carbon footprint is dominated by the energy used in actual supermarket stores – hence modelling can be based mainly on this core activity.
2) Participants that will be part of a sector that is heterogeneous in nature. For example local authorities will always have a complex mixture of activities including offices, schools, etc. The modelling of sectors like this must be done with great care. For this category there will be no ambiguity about sector as the participant can easily be mapped into the correct sector.
3) Participants that span more than one sector, without a dominant activity. Some CRC participants may span several sectors (e.g. offices, retail, light industrial). The carbon footprint might be spread fairly evenly across these sectors which will make mapping into the correct sub-sector quite difficult. This awkward category should be given further thought when the next stage of modelling is being considered.

Taking all of the below points into consideration an improved set of CRC sectors and subsectors has been developed as shown in Table 7.

Table 7 Recommended CRC sectors and sub-sectors

High Level CRC Group	CRC modelling sector	Subsectors included
Private sector industrial	CCA "industrial fragments" (These sectors have significant CCA exclusion. The remaining "fragments" will not be related to the main industrial process and can be modelled as a single group. This group will be a mixture of office activities, warehousing and light industrial activities).	Iron and steel Non-ferrous metals Mineral products Chemicals Food & beverages Textiles & leather Paper & printing Energy supply Agriculture Industrial laundries
	Mechanical engineering & metal products	
	Electrical & instrument engineering	
	Vehicle manufacture	
	Rubber and plastics	
	Water	
	Other industrial activities	Construction Mining of metal ores Manufacture of wood and products of wood Manufacturing not elsewhere classified Recycling
Private sector commercial	Offices	
	Supermarkets	
	Department stores / malls	
	Small shops	
	Storage & wholesale	
	Hotels	
	Restaurants	
	IT & internet	
	Other commercial activities	Rental, R&D, recreational, cultural, sport
Public sector	Central Government	All departments and associated bodies
	Local Government	Including LA schools
	Education	Further education and private schools
	Health	

Source: SKM Enviros, Ecofys, Entec (2010)

7.5. CRC Sector Coverage Estimates

7.5.1. Policy changes impacting on coverage

It is expected that CRC coverage would change as a result of the following policy changes since the initial Enviros/ NERA estimates were made in 2006[29]. The DECC Final IA 2009 did not attempt to revise coverage estimates originally from Enviros/ NERA 2006, due to a lack of available data on coverage and abatement potential. Table 6 shows that the limited revisions for EA 2009 work refer to coverage in the public administration and water subsectors.[30] This is despite the fact that the coverage rules had changed considerably since 2006.

The main policy changes affecting coverage are:

- increase in HHM electricity consumption threshold from 3,000 to 6,000 MWh/ year;
- 25% rule introduced for organisations with CCAs: organisations with at least 25% of its energy use emissions covered by a CCA are now eligible for a full exemption from the CRC;
- introduction of the 'Schools rule' which means that local authorities are now responsible for emissions from all schools maintained by that authority and any Academies and City Technology Colleges that are that are geographically located in the area for which the local authority exercises educational functions;
- mandatory participation for central government departments, irrespective of size;
- new CCA industry sectors introduced since 2005 e.g. plastics, laundries and cold stores.

There are other policy changes considered to impact on estimates of CRC coverage to a lesser or unknown extent including for example changes in the definition of transport in the transport exclusion which could increase the emissions coverage in some sectors[31].

Expert opinion for example gathered through discussion with industry [32] suggests that coverage of some sectors will have increased while for others it will have decreased. Using the new sector and subsector structure outlined in Table 7, the next section describes revised estimates of the sector and subsector emissions used as the base year for the modelling for this project.

[29] DECC unpublished
[30] EA effort focused on updating 'those subsectors known to be important or expected to be different from the estimates'. From the Enviros/ NERA 2006 coverage estimates these subsectors were: hotels and restaurants, other industries, public administration, retail trade, steel and wholesale trade, which accounted for over 62% of the total CRC coverage. Information through the industry bodies for retail, hospitality and steel was not available, and for the NHS was not considered sufficiently robust to include in the EA 2009 study. The only sectors which therefore were updated were public administration and water.
[31] where there is an unmetered supply participants can choose to include transport at the point of registration
[32] SKM Enviros, Ecofys, Entec UK (2010)

7.5.2. Revised estimates of sector size and coverage

This work provides a much better understanding of CRC sectoral emissions and updates the estimates of CRC coverage on the basis of the policy in its final form.

The overall estimate of CRC coverage provided below lies between 61.2 and 73.5 $MtCO_2$. The lower value of this range of estimates for a 6,000 MWh HHM electricity consumption threshold is higher than the previous highest estimate of CRC coverage from the EA in 2009 (57.5MtCO2). This reflects a much better understanding of the CRC sectoral emissions and how the CRC sectors are impacted on by the policy in its final form e.g. through the CCA 25% rule.

The detailed subsectoral estimates are in Appendix D and are summarised in Table 8.

- **Table 8 High level CRC group base year coverage estimates for 6,000 MWh threshold**

High Level CRC Group	Total 2008 UK Emissions (including CCAs and EU ETS) ($MtCO_2$)	CRC Base Year Emissions (MtCO2)	
		Low Scenario ($MtCO_2$)	High Scenario ($MtCO_2$)
Private sector industrial	172.7	18.12	22.93
Private sector commercial	58.9	27.57	33.05
Public sector	25.4	15.54	17.05
Total CRC coverage (MtCO2)	**235**	**61.2**	**73.5**

Source: SKM Enviros, Ecofys, Entec UK (2010)

7.5.3. Basis of new sector coverage estimate: DUKES data

The above sectoral estimates above were derived in conjunction with AEAT. The following steps were undertaken provide these base year estimates of CRC sector size and coverage:

1) Data from the Standard Industrial Classification (SIC) was used to ensure all relevant CRC sectors were identified.
2) Energy consumption data for 2008 from the Digest of UK Energy Statistics (DUKES) was used to define the energy use and CO_2 emissions from each main sector.
3) Data from DUKES and other published sources was used to disaggregate some of the sector data into more granular sub sectors.
4) The 55 CCAs were mapped into relevant CRC sectors.
5) The amount of EU ETS and CCA coverage in each sector was estimated using published emissions data for these schemes.

6) The impact of the CCA 25% rule was estimated based on expert opinion from industry knowledge. For each sector it was then possible to estimate the potential CRC coverage, excluding CCAs and EU ETS.
7) For the residual amount of emissions a further expert estimate was made to identify the quantity of energy above a 6,000 and 3,000 MWh threshold.
8) Due to the significant uncertainties, especially in steps 6 and 7 above, low and high sectoral estimates were made.

Using DUKES 2008 data is acceptable because the modelling includes the impact of a decline in emissions in 2009 due to the factors being used to project emissions from the base year of 2008 onwards. From summer 2012 there will be two years' worth of real base year data available for CRC specific analysis.

It was not possible to ascertain the various modelling assumptions used in DUKES 2008 data.

An analysis of DUKES 2008 sectoral data showed that there were discrepancies in energy use for a small number of sectors once CCA and EU ETS energy had been netted off the totals for these sectors. Quantities of energy use remaining after the netting off were shown to be negative while for other sectors quantities appeared to be too great. The high level sum total however provided a quantity of energy use which was broadly in line with what was expected.

8. Modelling the CRC cap

8.1. Introduction

This chapter provides a summary of the simple flexible modelling tool developed for this project to enable CCC to project CRC baseline emissions and emission reduction potential by subsector (public, commercial and industry) and for each of the DAs to 2022. The model has been developed to provide estimates of emissions reduction potential by subsector and by measure (energy efficiency, renewable electricity and heat). The model is flexible to allow inputs/ assumptions to be changed through a control panel to allow the CCC to manipulate a series of assumptions in order to explore different CRC cap levels.

This modelling provides an improved assessment of abatement potential in comparison to previous work on the basis of:

- the selective mapping of ENUSIM sectors to CRC sectors;
- the segregation of ENUSIM and N-DEEM technologies into four groups to enable differentiated uptake rates to be applied to them; and, use of relative not absolute abatement potentials.

This section is structured as follows:

- section 8.2 provides an outline of the model components;
- section 8.3 outlines the emissions under the BAU scenario;
- section 8.4 summarises the abatement potential component of the model;
- section 8.4 highlights the assumptions used in abatement potential modelling; and,
- section 8.5 briefly discusses the consistency of assumptions used in this modelling;
- section 8.6 maps the abatement potential from ENUSIM and N-DEEM into the CRC subsectors and to energy data;
- section 8.7 outlines the cap calculation.

8.2. Model Components

The model consists of several components which are combined to produce cap estimates:

1) Base year emissions. These have been estimated in this study as described below but when the first reporting under the CRC is complete in July 2011 real figures will be available and can easily be entered into the model. The base year emissions have been calculated by the project team using a range of sources. See section 7.5 for full details.

2) Calculation of the emissions during the capped periods (ending in 2017 and in 2022) under a business as usual (BAU) scenario.
3) Calculation of the potential for abatement through energy efficiency in the capped periods and as an option, the abatement through renewable electricity and renewable heat.
4) Calculation of the cap by subtracting the abatement potential from the business as usual emissions.

8.3. Emissions in a Business as Usual (BAU) Scenario

8.3.1. BAU projected emissions

Business as Usual (BAU) projected emissions are determined by the change in energy demand in a particular sector due to changes in the energy use drivers. Growth drivers are either economic or population depending on the sector (e.g. industry sectors are driven by GDP whereas health and education are driven by population). The BAU projected emissions scenariomust also take into account changes in energy efficiency i.e. energy use per unit of demand and changes in the fuel mix in the sector and/or the power generation sector.

8.3.2. Using the new modelling to specify growth rates

In the model users can separately specify two sets of growth rates from base year emissions, to show the effects of different drivers on growth rates. The mix of fossil fuels used and the emissions factors for electricity can also be varied by the user.

8.3.3. DECC LCTP energy model projections: used for new modelling

For the modelling results presented in this report, a combined factor for change in demand and improvements in energy efficiency was used derived from the DECC energy modelling for the low carbon transition plan[33]. The factor was derived from the baseline projections of energy demand by sector, which excludes the policies (including the CRC) set out in the low carbon transition plan but includes the effect of other Government policies in place before the Low Carbon Transition Plan (LCTP) e.g. Energy Efficiency Commitment (EEC) 1 and 2, and CCAs.

By using the sector specific growth factors from the LCTP projections the modelling excludes the policies which do not apply to or impact on a CRC sector when projecting emissions forward under

[33] Also known as UEP 38: http://www.decc.gov.uk/en/content/cms/statistics/projections/projections.aspx
Each year DECC publishes updated energy projections (UEPs), analysing and projecting future energy use and carbon dioxide emissions in the UK. The projections are based on assumptions of future economic growth, fossil fuel prices, UK population and other key variables. A set of projections is based on a range of assumptions to represent the uncertainty in making such projections into the future. These projections are consistent with the most recent UK budget announcements and include all firm and funded environmental policy measures. They are used to inform energy policy and associated analytical work across Government departments.

BAU. The modelling does not exclude the policies that apply to a CRC sector, see section 10.5.3 for discussion on carbon savings attributable to other policies.

Projected emissions decrease from 2009 to 2011, as the DECC energy model provides negative growth rates for all subsectors.

The growth rates in the LCTP central scenario, used as described in section 10, are shown in Appendix E.

8.3.4. Energy efficiency improvement

Assumptions about ongoing energy efficiency improvement are neither static nor rising. The DECC energy projections (LCTP) assume a constant rate of improvement for each sector. For each sector this is the underlying historic improvement assumed to continue at the same rate.

It is observed that even in the absence of policy in a particular area there is generally a trend for improving energy efficiency in a sector due to for example improvements in technologies. This is referred to within the actual modelling as 'autonomous improvement' and is the reason for using the combined driver for emissions that factors in both growth and/ or reduction in a sector and improvements in energy efficiency in the absence of the CRC policy.

8.3.5. Application of DECC energy projections to CRC subsectors

The modelling uses granular growth factors for commercial, public and industry which have been taken from the DECC energy projections (LCTP). These are applied to the CRC sectors commercial, public and industry.

8.4. Abatement Potential

8.4.1. ENUSIM and N-DEEM abatement potential

The ENUSIM and N-DEEM models were used as the primary basis for modelling abatement measures. While both models represent the most broadly accepted sets of abatement measures for industry and the non-domestic non-industrial sectors, neither were designed nor updated with the CRC in mind – both therefore have severe limitations for modelling the CRC cap, see section 5. Within the scope of this project, it was not possible to amend the models directly, however the best efforts were taken to work within these limitations and produce maximum value from the off-models for this project. Hidden costs (such as the time taken to research an abatement measure and develop a business case for its implementation) and benefits associated with implementing the abatement potentials were not included due to limited data availability.

ENUSIM and N-DEEM 'off-model' spreadsheets were used in this project. These spreadsheets take the results from the main models and allow the user to recalculate the costs associated with each measure according to a new set of parameter values. The spreadsheets do not recalculate the energy savings associated with each measure.

The MACCs provided by ENUSIM and N-DEEM give a static picture of the abatement potential at a particular time but do not give an indication of the period in which they can be applied. An important step in the modelling is therefore to define scenarios to convert the total potential to that which can be implemented in a capped period.

Both models provide MACCs in terms of tonnes of carbon abated based on specific baseline scenarios for total emissions in a given sector. To use these in the modelling for the CRC cap, the absolute values were converted to percentage reductions. These percentage reductions were then applied to the CRC emissions baseline at the sector level according to the mapping below.

8.4.2. Energy efficiency abatement potential in the capped periods

The MACCs from ENUSIM and N-DEEM are both derived from runs that assume business as usual uptake of energy efficiency technologies up to the period of the MACC i.e. the MACC for 2012 assumes a certain uptake of technologies up to 2012[34]. The model therefore accommodates for energy efficiency that would be expected under BAU between the footprint year and 2013 using the MACCs. In theory, since the model provides the capability, an additional growth rate, perhaps negative, could be applied to show energy efficiency improvement – however projected growth rates are already low in the model as they are.

N-DEEM and the Market Transformation Programme (MTP)[35]

The modelling for this project has taken into consideration any carbon savings derived through the MTP. The N-DEEM MACC was updated in 2006 to take account of the MTP in two ways:

1) The energy use in non-domestic buildings in 2006 was reconciled with actual data from national statistics and therefore any impacts from the MTP have been included in the N-DEEM baseline.
2) In addition, measures included in the model and their relative penetration rates assumed by BRE are based on information from the MTP.

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[34] The BAU runs in ENUSIM and N-DEEM were for a previous study and therefore energy prices and growth rates may not be identical to the assumptions here. It was not possible in this study to re-run ENUSIM and N-DEEM

[35] The MTP supports the development and implementation of UK Government policy on sustainable products. MTP reduces the environmental impact of products across the product life cycle through several means.

Technology penetration rates and technology categories

The technologies in the off-models could not be updated for individual penetration rates. To be able to do so would involve great volumes of cost data on the existing measures within each of ENUSIM and N-DEEM which could not be resourced, and are not necessarily available for use, within this project. To respond to this limitation the method described below was developed to be able to give different groups of measures different penetration rates. To calculate how much of the potential identified in the MACCs could be implemented in the capped period, the measures in N-DEEM and ENUSIM were grouped into the following categories:

1) Behavioural – including energy management and low cost control systems.
2) Retrofit – require moderate capital spend. Includes installed control systems, high efficiency motors, soft start and waste heat recovery.
3) Plant replacement for technologies with long replacement cycles, i.e. the lifetime of the technology is around 25-30 years (e.g. boiler replacement, process plant replacement).
4) Plant replacement for technologies with short replacement cycles, i.e. the lifetime of the technology is around 10 years (e.g. office equipment).

Note that the last grouping of measures was only relevant for N-DEEM measures, since ENUSIM measures are focussed on heavy industry and the replacement of technologies on long rather than short replacement cycles. ENSUIM measures were grouped into the first three categories.

Technology uptake during the capped phases

As discussed previously, there are two ‘uptake’ factors that are relevant to the discussion of the cap. How much of the technology potential is taken up under BAU and how much of the remaining potential could be taken up in the capped period.

The MACC for both periods already assumes a BAU level of uptake of technologies to the start of the capped period. It is assumed that this uptake is compatible with the DECC energy modelling of the baseline to 2018, but because of the two very different sources it is not possible to be confident that this is fully consistent.

For the remaining potential, a different proportion of each of these groups of measures is assumed to be taken up in each of the 5-year capped phases. These proportions are specified in Table 9, with reference to the following uptake (or penetration) scenarios, developed in conjunction with CCC:

- Maximum scenario: this assumes that all available measures are undertaken;
- High scenario: this assumes a small restriction on capital spend and willingness to install, and some early retirement of plant technology;

- Central scenario: this assumes there are greater incentives than in the low scenario for installing measures but some restrictions to installation remain e.g. from capital availability etc.;
- Low scenario: this assumes that the incentive to invest in low carbon technology is not strong enough to overcome other barriers.

A series of uptake rates per measure type were developed for each scenario, based on the most up-to-date uptake rates in ENUSIM (updated in 2010). The ENUSIM uptake rates were based on three sources of expert judgement:

- direct industry consultation;
- Ecofys/ SKM Enviros industrial energy efficiency experts; and,
- AEA CCA experts.

The ENUSIM uptake rates were then reviewed by Ecofys and SKM Enviros experts to develop the uptake rates appropriate for CRC sectors.

Expert opinion of the project team suggests that BAU in the CRC sector generally is likely to be nearer the low scenario of uptake based on the UK's historical low penetration for energy efficiency in these sectors.

The level of uptake in the first capped phase will affect the amount of abatement available for uptake in the second capped phase so uptake rates were developed for a number of combinations of scenarios between the first and second capped phases. For example, a high level of uptake in the first capped phase was modelled with a low level of uptake in the second capped phase and vice versa.

Table 9 Measure uptake rates for 2013-2017 and 2018 onwards

Scenario		Measure type							
		1		2		3		4	
2013-2017	2018 -->	2013-2017	2018 -->	2013-2017	2018 -->	2013-2017	2018 -->	2013-2017	2018 -->
High	High	100%	10%	80%	20%	25%	25%	60%	40%
High	Central	100%	10%	80%	10%	25%	20%	60%	30%
High	Low	100%	0%	80%	10%	25%	5%	60%	20%
Central	High	100%	10%	60%	40%	20%	25%	50%	50%
Central	Central	100%	10%	60%	40%	20%	20%	50%	50%
Central	Low	100%	0%	60%	30%	20%	15%	50%	40%
Low	High	80%	20%	40%	60%	15%	25%	40%	60%
Low	Central	80%	20%	40%	60%	15%	20%	40%	50%
Low	Low	80%	20%	40%	50%	15%	15%	40%	40%
Max	Max	100%	10%	100%	10%	25%	25%	100%	10%

Notes: Type 1 – behavioural measures; type 2 – retrofit measures; type 3 – plant replacement (long cycle), and type 4 – plant replacement (short cycle). Source: SKM Enviros, Ecofys, Entec UK (2010)

8.4.3. Overlapping measures and low carbon supply

Overlapping measures

In general ENUSIM abatement measures were applied to the CRC industry sector and N-DEEM abatement measures were applied to the CRC commercial and public sectors. There was no double counting therefore on the measures applied to a single sector. See section 5.2.4 for more information on how ENUSIM and N-DEEM avoid double-counting of abatement potential.

Low carbon supply and renewables overlap

To examine the effect of low carbon supply on the cap, the model allows the user to opt to include the emission abatement potential available from renewable electricity and from renewable heat supply. Certain technologies such as solar water heating and ground source heat pumps have been analysed as part of the N-DEEM model and in the renewable heat study. To avoid overlap with the renewable heat measures[36] taken from the CCC 2009 study (based on the NERA heat modelling work) used in this modelling, only solar-photovoltaic (PV) was used from N-DEEM.

[36] air source heat pumps, ground source heat pumps, biogas combustion, biomass boilers and CHP, and solar thermal

Renewable electricity modelling

Cost data were cross-checked with the Element Energy/ Poyry report for the Feed-in-Tariff scenario analysis[37]. It would be difficult to split the amount of savings between the CRC and FITs because the background FITs study was based on national figures and there is not enough information to be able to extract the necessary data on non-domestic CRC buildings.

The renewable electricity potential identified for this project therefore is a figure from N-DEEM for overall potential that is possible in the non-domestic sector. The renewable electricity savings were modelled with central fuel prices at a 3.5%, 10% and 15% discount rate. The renewable measures in N-DEEM are estimated individually and not in combination with other measures. The assumptions for this renewable electricity potential are in Appendix G (and more information about the N-DEEM model data source and assumptions can be found in the supporting document submitted by BRE to the CCC (2008)).

Renewable heat modelling

A CCC worksheet (2009), based on the outputs of the NERA model (2009), was used to provide data on renewable heat measures. The CCC worksheet provides:

- renewable heat projections (abatement potential and its £/MtCO_2 cost) for the whole of UK in 2012, 2017, 2020 and 2022;
- split by technology type (e.g. solar thermal, GSHP, biomass boilers, etc.);
- by sector (i.e. between domestic, industry, public and business/commercial); and,
- for 4 uptake scenarios (maximum technical potential, central feasible, high feasible and low feasible).

From this set of data, marginal abatement curves for 2012 and 2017 were calculated, as follows:

- Step One: Since the NERA heat model provides total UK heat, the results were scaled from UK total to CRC total. This was done on a per sector basis for the public, business and industry sectors. To do this, the CRC emissions calculated as outlined in section 7, for this study were divided by the total emissions for that sector from DUKES, providing a % of the CRC portion of each sector within total UK. Since it is heat only which is being considered, only the fossil fuels baseline was taken from the CRC cap model (i.e. electricity was excluded) to represent total heat in the CRC, and only the oil, gas and heat figures were taken from DUKES, to represent total UK heat. The resulting % for each sector was 10% for industry,

[37] DECC (2009b)

74% for public and 81% for the commercial sector. These % figures have been sense-checked internally within Ecofys and with CCC.

- Step Two: The CCC worksheet was used to create whole-of-UK heat MACCs for each sector for 2012 and 2017 by summing the potential available at different cost thresholds for the industry, public and business/commercial sectors for the 4 uptake scenarios provided (maximum, central, high and low).
- Step Three: CRC heat MACCs were then created by multiplying the whole of UK heat MACC for each sector (from step two) by the % of that sector within total UK (from step one).

The result of the above calculation are heat MACCs in 2012 and 2017 for the commercial, public and industry sectors, showing 4 uptake scenarios (maximum, high, central and low).

There are two potential overlaps between energy efficiency and renewable electricity and heat:

1) There will be competition at a company level for the available capital which means that a company may choose to use that capital to invest in renewable energy and not energy efficiency (or vice versa). This is also true in general for any measures that compete for capital spend. This is not taken into account in the modelling.
2) Installing renewable generation will reduce on-site emissions. Under the current CRC rules, if the renewable generation is in receipt of government support via ROCs or FITs then the CRC participant must still buy allowances for the emissions from use of that electricity. In the modelling with renewable generation included, it is assumed that the energy efficiency measures will still be implemented and then emission reductions from renewable technologies are applied.

8.5. Consistency of Assumptions in Abatement Potential Modelling

The ENUSIM and N-DEEM off-models were run using the same set of discount rates, emission factors, fuel prices, uptake rates and time periods. This was to ensure consistency between the key assumptions in the abatement potentials produced from the two off-models.

8.6. Mapping Abatement to CRC Subsectors and Energy Data

8.6.1. Abatement potential mapped to CRC sectors

ENUSIM models abatement on a whole-of-industry-sector basis, without distinguishing between abatement opportunities for larger versus smaller organisations within a sector. The sector categories in ENUSIM which are dominated by large industry are of little help for CRC analysis. As discussed in section 6.3 the main ENUSIM evaluation in sectors like steel, chemicals etc. are for processes excluded from the CRC because of CCA coverage. Those sector categories which were considered most likely to have abatement opportunities the most closely aligned with CRC industrial sectors were used: these were mechanical engineering, electrical engineer and vehicle manufacturing.

The water sector is a separate sector in ENUSIM but data are unreliable and indicated only small emissions savings which expert review suggests is inaccurate. The mechanical engineering sector was used as a first estimate but it is recognised that this is not a good approximation for the water industry which is significant in the CRC.

N-DEEM provides a split into commercial and public sectors only. As discussed in section 6.3 this split will not give sufficient granularity to assess widely differing types of non-domestic building, but currently this is the best MACC analysis available. These were mapped to the CRC commercial and public sectors identified in section 7.5.

Table 10 below provides a description of how CRC sectors were mapped to N-DEEM and ENUSIM sectors to match the abatement potential with the relevant CRC sectors as accurately as possible within the constraints of N-DEEM and ENUSIM.

Table 10 Mapping of N-DEEM and ENUSIM abatement potential to CRC sectors

CRC subsector	CRC sector	N-DEEM sector used	ENUSIM sector
Mechanical Engineering	Industry		Mechanical Engineering
Electrical Engineering	Industry		Electrical Engineering
Vehicle Manufacture	Industry		Vehicle Manufacture
Rubber and plastics	Industry		Mechanical Engineering
Water	Industry		Mechanical Engineering
Construction and other	Industry		Mechanical Engineering
CCA industry “fragments”	Industry	Commercial	
Supermarkets	Commercial	Commercial	
Dept Stores	Commercial	Commercial	
Small Shops	Commercial	Commercial	
Wholesale	Commercial	Commercial	
Hotels	Commercial	Commercial	
Restaurants	Commercial	Commercial	
Offices	Commercial	Commercial	
IT and Internet	Commercial	Commercial	
Storage	Commercial	Commercial	
Other (inc. Media, Sport)	Public	Public	
Central Government	Public	Public	
Local Government	Public	Public	
Health	Public	Public	
Education	Public	Public	

Source: SKM Enviros, Ecofys, Entec UK (2010)

8.6.2. Mapping CRC subsectors to energy data

The CRC subsectors are mapped to energy data from DUKES, shown in section 7.5.2. In addition to this selective mapping of ENSUIM and N-DEEM subsectors to CRC sectors, the abatement potentials reported from ENUSIM and N-DEEM were normalised to CRC sector level of energy consumption. This was done by converting the absolute emission reductions reported by ENUSIM and N-DEEM to relative emission reductions (i.e. %) by dividing them by the base year emissions in ENUSIM and N-DEEM.

These relative emission reductions were then multiplied by the CRC base year emissions to provide the absolute emission reductions for CRC participants. This takes into account that the ENUSIM and N-DEEM sectors (and therefore the base year data and absolute abatement potentials correlating to those base years) do not provide an exact fit to CRC base year data and hence CRC absolute abatement potentials. However, the relative emission reductions figures from N-DEEM and ENUSIM are expected to better represent the abatement potential for CRC sectors than the absolute emission reduction figures provided by the off-models.

8.7. Calculation of the Cap

The abatement potential for a capped phase is defined by the MACC from the year before the start of the capped phase. The abatement at the end of the capped phase is calculated using one of the scenarios described in section 8.4. The cap at the end of the phase is therefore calculated from the business as usual emissions for that year minus the defined abatement potential. The intermediate year caps are calculated using the business as usual emissions and assuming a linear annual decrease in the defined abatement potential from the start of the period to the end year. The difference between the emissions in 2013 and the cap is not the savings delivered from the CRC but a combination of the effect of all policies acting on emissions. The modelling does not enable the user to identify the savings attributed solely to the CRC. For discussion of carbon savings attributable to other policies see section 10.5.3.

9. Model parameters and design

9.1. Introduction

This section provides the details of the modelling approach taken for this work. The modelling has been designed to allow estimates to be made of the potentials savings which could be made cost-effectively up to a certain carbon price using a series of assumptions to define by when these savings could be achieved.

It is structured as follows:

- section 9.2 summarises the model design and variable parameters;
- section 9.3 provides details of the data sources used by the modelling; and,
- section 9.4 outlines the limitations to the modelling approach taken for this project.

This report is accompanied by the model and a guidance note which provides more detail on the model and a worksheet-by-worksheet description of how the model operates and how data in the model can be updated.

9.2. Outline of Model Design

The model consists of two key sheets where parameters can be varied (the control panel and reported data sheet) and an outputs sheet (the 'output' sheet), where the final cap can be seen. The remaining worksheets are data, information or calculation sheets. The guidance note provides a detailed worksheet-by-worksheet description of the model.

9.2.1. Control panel and variable parameters

The 'control panel' sheet allows the key modelling parameters to be varied, as follows:

- Energy prices. Energy prices are fully flexible, i.e. the user can input a specific set of fuel prices to run through the model, or else select from a high, central or low energy prices scenario.
- Emission factors. Emission factors are fully flexible and provided in a time series, i.e. the user can input any set of year-on-year emission factors to run through the model.
- Baseline year (or base year). The base year is fully flexible between 2009 and 2017, i.e. the base year can be specified as being any one of these nine years.
- Capped period. The model enables the user to select from one of two capped periods to model the cap for; either for the end of the first fixed period 2017 or for the end of the second fixed period 2022.

- Growth rates. Growth rates are fully flexible and can be entered as annual values for each subsector of the CRC.
- Technology penetration rates. The model enables the user to choose from four technology penetration scenarios: low, central, high and maximum uptake.
- Carbon price. The carbon price is fully flexible, i.e. the user can input any carbon price to run through the model.
- Discount rate. The model enables the user to choose from one of three discount rates: 3.5% (social discount rate), 10% and 15%.

9.2.2. Reported data sheet

The ‘Reported data’ sheet provides the baseline emissions data and is hard-coded data, which can be updated and has the following flexible parameters:

- Base year or baseline energy data. The base year energy data is fully flexible, i.e. the user can input any set of baseline data, within the format provided, to run through the model.
- CRC threshold. The model enables to user to choose from four CRC thresholds: either 3,000 MWh or 6,000 MWh, and with either a high or low estimate of CRC coverage for both.
- Regional split. The regional split of base year emissions and abatement opportunities is fully flexible and is able to be specified separately for electricity versus fossil fuels.

9.2.3. ‘MACC’ sheet

The ‘MACC’ sheet provides the abatement potential available for different scenarios. It is hard-coded data, with the capacity to be updated with new abatement potentials for these scenarios if required. For the modelling presented in this report, the off-model ENUSIM and N-DEEM spreadsheets were run to give a range of percentage emissions reduction by carbon price according to the different scenarios.

9.2.4. Output sheet and cap

The ‘output’ sheet provides the final cap, with the following detail:

- Calculation detail. The output sheet provides a diagram that transparently shows base year at the start of time period, growth over the time period, abatement achieved over the time period and final emissions at the end of time period (i.e. the cap).
- Sector detail. The output sheet shows not only the total cap, but also the contributions of the commercial, industry and public sectors and their subsectors (i.e. commercial subsectors, industrial subsectors and public subsectors) to the total cap.

- Energy detail. The output sheets shows not only total energy use, but also separately shows electricity use and fossil fuel use.
- Abatement measure detail. The output sheet shows the abatement contributions of energy efficiency measures, renewable electricity and renewable heat.

9.3. Data Sources

A list of data sources used in the model is provided below with more detail in the subsequent text.

- **Table 11 Data sources**

Data type	Data source
Energy efficiency measures	ENUSIM and N-DEEM (2002) off-models
Renewable electricity measures	N-DEEM off-model provided by BRE (2010)l
Renewable heat measures	CCC (2009)
Energy prices	DECC IAG[38]
Energy emission factors	DECC and EA CRC Guidance (2010)
Technology uptake rates (penetration)	Expert judgement
2009 base year data	DUKES 2008
Regional split	DECC[39]
Weighting factor for fossil fuels	DUKES[41]
Growth factors	DECC energy model[40]

Source: SKM Enviros, Ecofys, Entec UK (2010)

No further data is required to run the model. The guidance note provides detail about how to update data in the model, in particular reported base year data.

9.3.1. Fuel prices and emission factors

Energy use and abatement is split in the model between electricity and fossil fuels. Information on the fuel mix in the CRC sectors is not available so both the emission factors and fuel prices were based on an assumed mix of gas and oil. The data source for the weighting between gas and oil was

[38] DECC Inter-departmental Analysts Group (IAG), Table 1-29 for guidance on valuation of energy use and greenhouse gas emissions, Tables 10-15 (Energy Price - Low), Tables 16-21 (Energy Price – High), Tables 4-9 (Energy Price – Central), see Appendix F.http://www.decc.gov.uk/en/content/cms/statistics/analysts_group/analysts_group.aspxb

[39] http://www.decc.gov.uk/en/content/cms/statistics/regional/regional.aspx

[40] http://www.decc.gov.uk/en/content/cms/statistics/projections/projections.aspx

Each year DECC publishes updated energy projections (UEPs), analysing and projecting future energy use and carbon dioxide emissions in the UK. The projections are based on assumptions of future economic growth, fossil fuel prices, UK population and other key variables. A set of projections is based on a range of assumptions to represent the uncertainty in making such projections into the future. These projections are consistent with the most recent UK budget announcements and include all firm and funded environmental policy measures. They are used to inform energy policy and associated analytical work across Government departments.

taken from the Digest of United Kingdom energy statistics data[41] (DUKES). The ratio of petroleum products to gas in thousand tonnes of oil equivalent for the mechanical engineering sector (13%: 87%) was used as a proxy for the ratio of oil to gas use in the CRC sectors.

Emission factors were taken from Government and Regulator guidance[42] for electricity, gas and gas oil. These emission factors are provided in the model as a time series, and the user is able to change the emission factors to any value for any year.

Energy prices were taken from DECC Inter-departmental Analysts Group (IAG)[43] guidance. The central, low and high scenarios were taken for electricity, gas and fuel/heating oil. These fuel prices were run through the off-models and are used to give three sets of abatement potential, one for each fuel price scenario. The user is able to input any fossil fuel price into the model as long as it is between the low scenario price and no higher than the high scenario price. The model interpolates between the three sets of abatement potential (i.e. low, central and high) to provide the abatement potential for the fuel price inputted. To allow the user full flexibility to input a large range of fuel prices, the variable element-commercial and variable element-industrial prices from the IAG guidance were used. This means that the user can adjust the fuel prices for the commercial and industrial sectors but must select the energy prices consistent with the discount rate they are using i.e. for 3.5% it is the variable component as required by IAG guidance.

9.3.2. Cost effectiveness calculations

Neither N-DEEM nor ENUSIM use Net Present Value (NPV) in their cost effectiveness calculation[44]. NPV calculations could not therefore be included in the model for CCC. Cost effectiveness in ENUSIM and N-DEEM is calculated from the annualised capital cost, which is dependent on the discount rate.

9.3.3. Base year data

See section 7.5 for more details of how base year data was calculated.

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[41] Dukes, Chapter 1 (Energy) Page 27, Table 1.1: Aggregate Energy Balance 2008 http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx.

[42] CRC Energy Efficiency Scheme Order: Table of Conversion Factors: Version 1 http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/crc/user_guidance/user_guidance.aspx

[43] DECC Inter-departmental Analysts Group (IAG), Table 1-29 for guidance on valuation of energy use and greenhouse gas emissions, Tables 10-15 (Energy Price - Low), Tables 16-21 (Energy Price – High), Tables 4-9 (Energy Price – Central).http://www.decc.gov.uk/en/content/cms/statistics/analysts_group/analysts_group.aspxb

[44] For example, ENUSIM does a simple capital cost + annual maintenance cost type of calculation, without taking NPV into account.

9.3.4. Carbon price

Carbon prices provide a cost-effective threshold for the abatement potential taken up, i.e. if a given carbon price is assumed then it is reasonable to set a cap based on the assumption that all measures up to that carbon price will be realised in the CRC sectors.

Energy efficiency abatement potentials were taken from ENUSIM and N-DEEM for the following range of carbon prices: 0, 10, 20, 30, 40, 50, 100, 200, 500 and 1000 £/ tCO2.

Renewable heat abatement potentials were taken from the CCC report (2009) for the following range of carbon prices: 0, 10, 25, 50, 75, 100, 150, 200, 300 and 1000 £/ tCO2.

The model then interpolates between the abatement potential at these prices to provide abatement potentials with full flexibility for any carbon price.

9.3.5. Regional split

The model provides a split, between England, Northern Ireland, Scotland and Wales based on DECC energy use data[45].

The regional split is applied to the whole-of-UK 2009 base year data. When reported data is provided for 2010 it will need to be assessed against the split provided in the modelling, see section 12 for more detail. This is because reporting of emissions to the EA will not allow for DA split if a participant's operations span more than one DA.

The regional split is also applied to the renewable electricity and renewable heat abatement potential, so that a regionalised renewable abatement potential can be expressed for the final cap for 2017 and 2022.

Energy efficiency abatement potentials from N-DEEM and ENUSIM have been modelled for the UK as a whole and are not provided on a regional basis. However, the national energy efficiency abatement figures are apportioned to each region based on base year energy use in England, Scotland, Wales and Northern Ireland.

9.3.6. Growth rates

The model allows for two fully flexible sets of growth rates to be applied to the base-year data. This provides the advantage that, say, known DECC growth rates can be applied, and then a second set of growth rates to, say, take into account changing economic conditions can also be applied.

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[45] http://www.decc.gov.uk/en/content/cms/statistics/regional/regional.aspx The industrial/commercial regional split was used as a proxy for the regional split for CRC.

At present, the second set of growth rates are set to zero, so that only the DECC growth rates are applied in the model.

9.4. Limitations to This Approach

There are several key limitations to this approach.

The CRC base year emissions are not currently well understood, including total CRC emissions, the regional and subsectoral splits. This limitation will be reduced once the first full set of reported data is available in July 2010, see the note above on DA split.

The primary databases used for energy efficiency and renewable electricity measures (i.e. N-DEEM and ENUSIM) were not developed to specifically represent the CRC sectors. ENUSIM places an emphasis on large industry and N-DEEM does not cover the range of building types relevant for CRC, as well as being a vintage dataset.

Examples of the types of measures relevant for CRC sectors that are not currently included in ENUSIM or N-DEEM are:

- Measures to improve the efficiency of boilers;
- Measures to improve the efficiency of refrigeration in supermarkets and depots;
- Measures tailored to leisure centres, hospitals, IT data centres, and other sectors with specific energy uses that differ to the office type building;
- Measures tailored to office buildings such as replacing equipment with the most efficient model, enabling sleep mode and turning off equipment when not in use, installing appropriate controls where not fitted, replacing lamps with more efficient lamps, efficient light fittings, daylight design methods, different air conditioning technologies; and,
- Measures tailored to smaller buildings such as small-scale air conditioning controls.

The above list of measures was developed using a small number of bottom up studies which detail energy efficiency measures installed across several sectors (CT 2009, CT unpublished).

Data on renewable heat abatement is not available specifically for the CRC sectors; hence renewable heat abatement, as described above, is a calculated figure. However, renewable heat abatement overall is small compared to energy efficiency and would not be expected to impact significantly on the cap.

We chose within this project to use outputs from the ENUSIM and N-DEEM off-models (and hence providing a 'look up' table of outputs from the off-models), rather than incorporate the ENUSIM and N-DEEM off-models directly within this model. The advantage of this approach is that the model is of a more manageable size, completes runs within seconds (rather than within hours, as per the off-models), and calculations and outputs are transparent and easily visible. The disadvantage of this approach however is that full flexibility is not possible in this model for several parameters (technology uptake (penetration) rates and discount rates). Also, additional technologies cannot be added to the off-models. Note that at the time of this project, the ENUSIM model was in the process of being updated and the results of this update were not available at the time the model was being developed. The update to ENUSIM was aimed at the CCA sectors and did not improve the quality of the data for the CRC sector. The N-DEEM model in its entirety was not available from BRE.

In addition the abatement potential does not increase under a scenario under which emissions increase. As explained by BRE in their technical documentation, the non-domestic MACC applies to the existing building stock, and therefore does not take into account of the potential for measures in new build. The analysis is based on a 'static' building stock, which means that the model estimates the savings that are still available in the current building stock in future years, without taking into account demolition rates or changes to the existing stock (for example, extensions, etc).

The user can select fuel prices etc. which change the specific costs (and therefore the savings delivered for a particular carbon price) but not the delivery from different technologies.

9.5. Advantages of this approach

The key advantage of this approach is that it is a transparent and user-friendly model which can be readily updated with reported CRC base year data as it becomes available. Where updated data is available on the CRC abatement potential, these potentials can be updated in the model. In addition, the model is fully flexible for a large number of parameters including energy prices, emission factors, growth rates and carbon price.

10. Cap levels

10.1. Introduction

As we have seen in other emissions trading schemes (like the EU ETS and the UK ETS), the level of the cap will be a key determinant of the success of the scheme in driving the uptake of energy efficiency measures and reducing emissions. If the cap is set too high, the scheme will deliver only limited additional carbon savings - the cap signal will not be sufficiently strong to incentivise these savings. If it is set too low, participants will be required to reduce their emissions further than may be cost effective or further than those organisations captured by other policies are required to do. This may in part depend on the relative opportunities for abatement in the CRC sector compared to other sectors. It is imperative that the cap is set using appropriate baseline and sectoral data in conjunction with CRC specific modelling tools. Key requirements for good cap setting are described in section 6.

This section outlines the outputs of the modelling undertaken for this project and is structured as follows:

- section 10.2 outlines the context in which the CRC cap will be set;
- section 10.3 details the approach to cap derivation taken in this modelling, including MACC principles and cap derivation going forward;
- section 10.4 outlines the assumptions the possible caps are contingent on;
- section 10.5 summarises the results of the CCC Central scenario modelled;
- section 10.6 summarises the possible caps generated through specific runs of the modelling completed for this project;
- section 10.7 outlines the renewable heat potential from the Renewable Heat Incentive (RHI) and how this compares to the contribution of renewable heat to the modelled caps;
- section 10.8 outlines discussion on the renewable electricity potential in the modelling;
- section 10.9 provides a short qualitative assessment of the uncertainties around the possible caps; and,
- section 10.10 provides concluding remarks on this section.

Please note that the review of ENUSIM and N-DEEM outputs for this project has identified serious shortcomings in their applicability to the CRC sectors and to CRC cap setting (see section 5). Given the project resources and timeframe it was necessary to use the outputs of these models but we urge caution on the use of the cap numbers which follow.

10.2. Context of Cap Setting

The CRC cap will need to be set by Government in the context of several factors outlined below.

- Domestic and European-level environmental objectives – i.e. the legally binding emission reduction domestic targets set by the Climate Change Act 2008 for 2020[46] and for 2050[47], the five-yearly carbon budgets to help ensure those targets are met, and the targets proposed by the European energy action plan[48] for the same period.
- The required split of effort between sectors covered by the CRC and those covered by other policy instruments e.g. the EU ETS. The required split of effort will in part be informed by business-as-usual projections and the real energy use data available from the CRC in July 2011[49]. Note that even a CRC coverage estimate based on real baseline data will still not allow a very robust estimate of abatement potential at a given carbon price if the abatement potential modelling is non-CRC specific (which is the case with the current ENUSIM and N-DEEM modelling.
- The split of effort will also need to take into consideration the balance between (a) energy efficiency measures from CRC organisations, (b) use of "local" renewable energy sources by CRC organisations (such as microgeneration and renewable heat) and (c) decarbonisation of energy supply streams as influenced by other policy measures.

[46] reduction of 34% in greenhouse gas emissions (this is the interim target)
[47] reduction of at least 80% in greenhouse gas emissions
[48] a legally binding reduction in the EU's greenhouse gas emissions to 20% below 1990 levels, by 2020; this would rise to 30 % in the case of an international climate change deal; a legally binding 20%increase (by 2020) in the amount of renewable energy consumed in the EU; a 20% reduction in the EU's energy consumption by 2020
[49] consideration must be given to the level of effort between sectors covered by each policy instrument. Under the EU energy package, the UK will have a reduction target for non-EU ETS sectors of 16% by 2020 compared with 2005 figures. Notably this is lower than the overall EU ETS target for the same period. The distribution of this between UK domestic measures should take account of abatement costs across the economy, to ensure lowest cost overall. Previous work noted that the CCC recommends emission reduction effort over the first three budget periods be split 70/30% between the traded/non-traded sectors (EA 2009) but the actual level of effort required by non-traded and traded sectors is 60/ 40 over the first three carbon budgets (CCC, 2010).

- Actual reported energy use data for CRC subsectors from the first two years of the CRC Introductory Phase. This data must be used to update the projections of the "base year" emissions from organisations participating in the CRC.
- The emissions abatement already achieved and the potential for further abatement from each CRC sector (from both energy efficiency and renewable heat and electricity).
- The projected rate at which the abatement potential represented by the MACCs will be realised (during and beyond the capped period). This rate is calculated from the aggregated result of the assumed implementation rates of each of the energy efficiency measures included in the MACCs. The implementation rate may be dependent on the cost of abatement, in terms of £ per tCO_2 abated. The implementation rate is also dependent on the extent to which non-financial barriers to implementation, such as lack of awareness of technologies, are overcome.

10.3. Approach to Cap Derivation

The approach taken to modelling possible caps for the CRC is outlined below.

- Define the baseline emissions year (2009) based on the total estimated emissions that will be covered by the CRC;
- Estimate the emissions trajectory from the baseline year up to 2022[50] in the absence of the CRC and Low Carbon Transition Plan policies (the Business As Usual (BAU) scenario). The emissions were estimated based on assumptions made on the year-on-year growth in emissions from the CRC sectors in the absence of the CRC (using DECC energy projections modelling);
- Estimate the cost effective technical abatement potential that could be implemented in the five-year capped period from energy efficiency measures and renewable energy based on modelled MACCs for each CRC sector;
- Calculate the CRC cap at the end of the first and second capped periods by subtracting the available abatement potential for each period under a certain cost (£/tCO_2) from the BAU emissions at the end of that period.

We have modelled caps for the end of the first capped phase (2017) and the end of the second capped phase (2022). The CRC requires annual auctioning of allowances by Government hence there will need to be a series of annual caps between the beginning and end of each period. At this stage we recommend a cap which is descending each year by a constant % between the beginning and end of each phase. We recommend that this assumption is reviewed if improved CRC abatement potential modelling is researched and carried out.

The modelling does not incorporate any take up of EU ETS emissions allowances through the safety valve. Cap values provided in this section are therefore absolute. If allowances are purchased through the safety valve then the actual emissions from the CRC sector will be higher than the cap by the amount of emissions purchased.

The above approach to cap derivation is underpinned by the following elements. For more detail on these see sections 8 and 9.

- **Baseline emissions year**: 2009 was defined as the baseline year (or base year), using emissions calculations based on DUKES 2008 figures which were apportioned to reflect the estimated CRC coverage of each sector for two CRC inclusion thresholds (6,000 MWh and

[50] CRC years are referred to in relation to their start year – hence 2022 relates to the CRC year that starts in April 2022 and finishes in March 2023

3,000 MWh), with a low and high coverage scenario for both thresholds. This is discussed in more detail in section 6.

- **Business as Usual (BAU) scenario**: projected emissions in the absence of the CRC from the baseline year up to 2022 were estimated using DECC's 2009 "Central" projections of percentage growth in GDP, as outlined in section 8.3. The impact of growth rates were modelled under additional high-growth rate scenarios.
- **Energy efficiency abatement potential**: estimates of the energy efficiency abatement potential for each of the CRC sectors were provided by a series of sector-specific MACCs generated using the ENUSIM and N-DEEM off-models[51]. The MACCs were generated using a range of assumptions on the uptake rates of energy efficiency measures; the abatement potential was calculated for different carbon prices. See section 8 for details of how the outputs from ENUSIM and N-DEEM have been scaled for the CRC sectors.
- **Renewable energy potential**: estimation for the entire CRC sector of the abatement potential from renewable electricity is based on N-DEEM and for renewable heat on a NERA study (for CCC study, 2009).
- **Energy prices**: three sets of energy prices (central, low and high scenario; using variable element prices) from the DECC Inter-departmental analysis Group (IAG) were used in the modelling of the abatement potential.
- **Energy emissions factors**: the modelling assumes a time series of fossil fuel and electricity emissions factors, taken from DECC's 2010 guidance on the CRC[52] . These factors are an input variable to the model and can be adjusted as required for e.g. the second capped phase.

10.4. Assumptions on Which Caps Are Contingent

We have investigated a range of CRC caps for the ends of the first and second capped phases (2017 and 2022 respectively) by simulating different scenarios under which one or more parameter values were modified. Our starting point was to run the model under a set of parameter values chosen by the CCC to represent a Central scenario. Descriptions of the different scenarios modelled and assumptions on which the resulting caps are contingent are outlined in **Table 12**.

[51] defined in section 5.2
[52] http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/crc/user_guidance/user_guidance.aspx

Table 12 Parameter values modified under different scenarios for cap setting

Scenario description	Carbon price* (£/ tCO2)	Discount Rate (%) (DR)	Fuel prices	Technology penetration rate	GDP growth/ output	CRC threshold (MWh)
CCC Central	0	3.5	Central - Variable**	Medium	Central***	6,000
Price of carbon variation	0, 50, 500	3.5	Central - Variable	Medium	Central	6,000
Discount rate variation	0	3.5, 10, 15	Central - Variable, Central Retail**	Medium	Central	6,000
Fuel price variation	0	3.5	Low, central high	Medium	Central	6,000
Technology penetration rate variation	0	3.5	Central - Variable	Low, medium, high	Central	6,000
Growth rate variation	0	3.5	Central - Variable	Medium	1%, 2%	6,000
Low CRC threshold variation	0	3.5	Central - Variable	Medium	Central	3,000

Note: the parameters varied from the Central scenario are highlighted by shading. * 'carbon price' does not refer to the EU ETS price here but the carbon price defining carbon savings available. ** 'Variable' fuel prices were used for the CCC Central scenario i.e. at 3.5% DR taken from DECC's Inter Departmental Analysis Group (IAG) projections (Tables 4-9). The 'Variable' category of fuel prices is also known as the 'Social' fuel prices. The retail ('Non Variable' or 'Fixed') fuel prices in the DECC's IAG projections are used for DRs of 10% and 15%. *** Central GDP growth rates are taken from DECC's energy projections for the LCTP, see Appendix E. Source: SKM Enviros, Ecofys, Entec UK (2010).

Energy to CO_2 emissions factors can be varied year-on-year in the model. The default values used for the emission factors are, however, held constant throughout each of the two phases, therefore the caps evaluated below do not take into consideration decarbonisation of the grid. These factors can be user adjusted in the model should evaluation of changes to these parameters be required at a future date.

The modelling was carried out using the "High Scenario" for baseline or base year emissions (73.5 MtCO2, see section 7.5.2). The baseline emissions from each CRC sector can also be adjusted in the model (for example when real data on base year emissions becomes available in summer 2011 and 2012).

10.5. Results of the CCC Central Scenario

10.5.1. Modelling results

Table 13 below summarises the results of the CCC Central scenario. Under this scenario the energy efficiency abatement potential at £0/tCO_2 for the end of the first capped period of the CRC (2017) is 16.1 MtCO_2 and for the end of the second period of the CRC (2022) is 23.3 MtCO_2. The resulting cap is 59 and 54 MtCO_2 for the first and second CRC periods respectively.

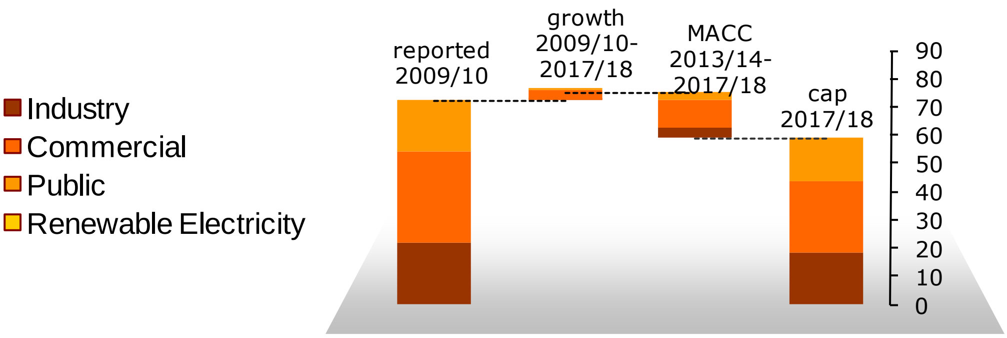
The models show that renewable electricity has no abatement potential and renewable heat only a small abatement potential at this price of carbon (£0/tCO_2) and hence only a small impact on the cap.

Table 13 Abatement potential and the cap under CCC Central scenario

Cap year	Carbon price £/tCO2	BAU emissions (MtCO2)	Cost effective efficiency abatement potential* (MtCO2)	Cap excluding renewables (MtCO2)	Renewables potential** (MtCO2)	Cap including renewables (MtCO2)	Reduction from BAU (%)
2017	0	75.0	16.1	59.0	0.1	59.0	21%
2022	0	77.0	23.3	53.6	1.4	52.2	32%

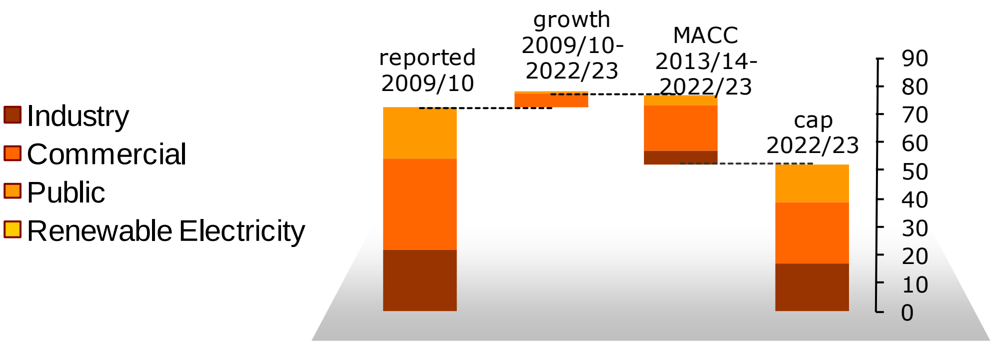
Notes: *Efficiency abatement potential from energy efficiency measures only - excludes renewable electricity and heat; ** Renewables includes renewable electricity and heat. Source: SKM Enviros, Ecofys, Entec UK (2010)

▪ **Figure 4 Illustration of cap derivation for the CCC Central scenario for Phase 1**



Source: SKM Enviros, Ecofys, Entec UK (2010)

▪ **Figure 4 Illustration of cap derivation for the CCC Central scenario for phases 1 and 2**



Source: SKM Enviros, Ecofys, Entec UK (2010)

10.5.2. New modelling compared to previous estimates

The year on year uptake of abatement potential is calculated using a two step process: 1) estimation of the total available for the whole 5-year time period; 2) assume a linear year-on-year uptake of that total over the 5 years (i.e. 20% of the total potential taken up each year). Hence, the abatement potential shown for a given year is the abatement potential available for the remainder of the 5 year period. In reality, uptake of the abatement potential may not be linear, as it will vary by measure, by CRC sector and by incentives offered by the CRC and other policies.

Table 13 shows the new estimates of abatement potential using the CCC Central scenario devised for this modelling. Estimates of abatement potential in previous CRC studies were described in

Section 5.4.3 and are listed in Appendix B. The new estimate is considerably higher than some of the previous estimates, although it is broadly in line with the most recent EA estimates. It is important to recognise that the saving potential is linked to the overall coverage of the CRC – the new "high scenario" estimated for this modelling indicates a higher level of coverage than previous estimates. Table 14 compares the latest figures with previous estimates. For easier comparison we have pro-rated all abatement estimates upwards to the current estimate of baseline coverage.

Table 14 Comparison of abatement potential estimates

Source	Base year emission $MtCO_2$	Year or type of estimate	Abatement estimate $MtCO_2$	Pro-rated abatement estimate for 73.5 base year emission $MtCO_2$
Current study	73.5	2017	16.0*	16.0
Current study	73.5	Total efficiency potential**	16.3	16.3
EA 2009	57.5	Cost effective	9.2	11.8
EA 2009	57.5	Cost effective	11.6	14.8
EA 2009	57.5	Total potential	16.0	20.5
DECC Final IA	53	2020	3.2	4.4
Enviros / NERA	50	2020	4.8	7.1
Enviros / NERA	50	Cost effective	7.9	11.6
Enviros / NERA	50	Total potential	12.1	17.8

Notes: CCC 2008 is not included in the above because it was not a CRC specific study. *abatement from energy efficiency measures only at carbon price £0/tCO_2, excludes abatement from renewable heat and electricity. **abatement from energy efficiency measures only at carbon price £500/tCO_2. Source: SKM Enviros, Ecofys, Entec UK (2010)

It is important to note that the current estimate is based on technical potential for saving compared to a BAU baseline – hence it is not policy specific (see next section). We believe that some of the very low estimates have taken into account overlaps with other policies and may have been based on a faster rate of economic growth (which pushes up BAU emissions).

10.5.3. Contribution of modelled abatement potential to budgets

The modelled emissions abatement potential represents the best estimate of cost effective energy efficiency savings and renewable energy savings for the CRC participants. This estimate is not policy specific – it is purely an evaluation of the technical potential for savings.

The actual savings will be driven by a number of policy measures including the CRC. In this section we comment on the overlaps between different policy measures that will affect CRC participants.

Savings in Traded and Non-Traded Sectors

We have estimated that around 70% of CO_2 emissions from CRC participants come from electricity usage and only 30% from fossil fuel usage. The electricity used comes from the "traded sector" as UK power stations are part of the EU ETS. The fossil fuel usage of CRC participants comes from the "non-traded sector" as it is not in the EU ETS[53].

In 2017 the modelled abatement potential for energy efficiency measures is 16.1 $MtCO_2$. Taking into account the split described above this implies that savings of 11.3 $MtCO_2$ will be from the traded sector and 4.8 $MtCO_2$ from the non-traded sector.

It should also be noted that the savings made in the traded sector will contribute towards the targets in the EU ETS. CCC may wish to consider whether this "undermines" the effectiveness of EU ETS targets.

Overlaps with other UK Polices

A range of existing policies that affects CRC participants are included in the Low Carbon Transition Plan. In addition to the CRC the LCTP includes the policies shown in Table 15. The overlap of each policy with CRC depends on which sector is affected by the policy. We have estimated that the following levels of overlap occur:

- Industrial polices — 13% of total LCTP savings for CRC participants
- Commercial polices — 56% of total LCTP for CRC participants
- Public sector policies — 69% of total LCTP savings for CRC participants

These figures have been used to estimate the degree of overlap with each policy in Table 15.

[53] Note, any fossil fuel used by a CRC organisation is specifically excluded from the CRC and has already been removed from the baseline estimates

▪ **Table 15 BAU and new LCTP policies affecting CRC participants**

Policy	LCTP Projected Saving $MtCO_2$		Estimated Saving from CRC Participants $MtCO_2$	
	2017	2022	2017	2022
Building Regulations (BAU)	2.4	2.3	1.0	1.0
Carbon Trust Measures (BAU)	0.8	0.8	0.3	0.3
Loans to Public Sector (BAU)	0.3	0.3	0.3	0.3
Products policy	1.9	2.5	1.1	1.4
Energy Perf of Buildings Directive	0.3	0.4	0.2	0.3
RHI	4.7	11.2	1.5	3.9
CRC	2.6	3.7	2.6	3.7
Total	13.0	21.2	7.0	10.9

Source: Data taken from LCTP and presented by SKM Enviros, Ecofys, Entec UK (2010)

The table illustrates an overall saving in BAU and the LCTP for CRC participants of 7 $MtCO_2$ in 2017. This consists of 2.6 $MtCO_2$ (37%) from CRC, 2.9 $MtCO_2$ (41%) from other energy efficiency policies and 1.5 $MtCO_2$ (21%) from the RHI.

The total contribution allocated to the CRC participants in the LCTP (7 $MtCO_2$ in 2017) is much lower than the emissions estimate made for the CCC Central scenario from this modelling (16.1 $MtCO_2$ in 2017). We believe this difference is caused by a combination of:

a) Lack of accuracy in ENUSIM and N-DEEM modelling;

b) Conservative savings assumptions for CRC used in the LCTP.

10.6. Sensitivity to Variation in Parameter Values

After establishing the cap under the CCC Central scenario we assessed the sensitivity of the model's results to variation in key parameters (as described in tables 16 to 21). The modelled cap showed some variation in response to an increase in growth rates and technology penetration rates but very little variation to changes in the carbon price, discount rate and fuel price.

Note the limitations of the models used as the basis for this modelling, detailed in sections 5.3 and 6. Expert opinion of the project team suggests that the lack of sensitivity to key parameters is due to (a) the measures in ENUSIM and N-DEEM which only include those which are cost-effective even at low CO_2 and energy prices and (b) the lack of CRC specificity.

10.6.1. Sensitivity of cap to carbon price (not EU ETS price)

Table 16 shows the variation in cap at £0 and £500 per tonne of CO_2. All other parameters are unchanged from the CCC Central scenario.

The modelled efficiency abatement potential shows almost no change across the range of CO_2 prices evaluated. For 2017, the efficiency abatement potential at £500 per tCO_2 is only 2% higher than at £0 per tCO_2. This highlights the already noted shortcomings of ENUSIM and N-DEEM as there should be a significant increase in abatement potential for such a large change in carbon price, see section 6.

The renewables potential increases at the higher carbon price as we would expect.

Table 16 Cap by carbon price for 2017 and 2022

Cap year	Carbon price £/tCO2	BAU Emissions (MtCO2)	Cost effective efficiency abatement potential* (MtCO2)	Cap excluding renewables (MtCO2)	Renewables potential ** (MtCO2)	Cap including renewables (MtCO2)	Reduction from BAU (%)
2017	500	75.0	16.3	58.7	5.8	53.0	29%
2017	0	75.0	16.0	59.0	0.1	59.0	21%
2022	500	77.0	24.0	53.2	13.0	40.3	48%
2022	0	77.0	23.3	53.6	1.4	52.2	32%

Notes: *Efficiency abatement potential from energy efficiency measures only - excludes renewable electricity and heat; ** Renewables includes renewable electricity and heat. Source: SKM Enviros, Ecofys, Entec UK (2010)

10.6.2. Sensitivity of cap to discount rate

Table 17 shows the variation in cap at a range of discount rates. All other parameters are unchanged from the CCC Central scenario except for fuel prices, which for DRs of 10% and 15% are the 'Retail' prices from DECC's IAG projections.

Increasing the discount rate from 3.5% to 15% resulted in a negligible decrease in the efficiency abatement potential (1% in 2017). It would be expected that high interest rates would result in a greater decrease than this. However ENUSIM and N-DEEM include only those measures which are cost-effective and have a 'good' payback, see section 6.

The impact on renewables abatement potential cannot be observed via a model run at £0 per tCO_2 (as illustrated in **Table 17**) because the potential is already zero. We have also run the model at £500 per tCO_2 and have found that increasing the discount rate from 3.5% to 15% has virtually no impact on the renewable abatement potential and the cap. The cap at the end of the second CRC phase with a carbon price of £500/ tCO2 and a discount rate of 3.5% is 40.3 $MtCO_2$ and with a discount rate of 15% is 40.6 $MtCO_2$.

Table 17 Cap by discount rate for 2017 and 2022

Cap year	DR (%)	BAU Emissions (MtCO2)	Cost effective efficiency abatement potential* (MtCO2)	Cap excluding renewables (MtCO2)	Renewables** (MtCO2)	Cap including renewables (MtCO2)	Reduction from BAU (%)
2017	3.5	75.0	16.0	59.0	0.1	59.0	21%
2017	10	75.0	16.0	59.0	0.1	58.9	21%
2017	15	75.0	16.0	59.1	0.1	59.0	21%
2022	3.5	77.0	23.3	53.6	1.4	52.2	32%
2022	10	77.0	23.2	53.8	1.4	52.4	32%
2022	15	77.0	23.1	53.8	1.4	52.4	32%

Notes: *Efficiency abatement potential from energy efficiency measures only - excludes renewable electricity and heat; ** Renewables includes renewable electricity and heat. Source: SKM Enviros, Ecofys, Entec UK (2010)

10.6.3. Sensitivity of cap to fuel price

Table 18 shows the variation in cap at a range of fuel prices. All other parameters are unchanged from the CCC Central scenario.

The fuel prices represent low, central and high scenarios in DECC's LCTP energy projections. Increasing the fuel prices to DECC's high fuel prices estimate resulted in a negligible increase in the efficiency abatement potential (under 1% in 2017). This is because the ENUSIM and N-DEEM models used as the basis for this modelling do not accurately represent the CRC sectors and the abatement measures appropriate to these sectors. We would expect more abatement potential as fuel prices rise.The impact on renewables abatement potential cannot be observed via a model run at £0 per tCO_2 (as illustrated in **Table 18**) because the potential is already zero. We have also run the model at £500/ tCO_2 and have found that increasing the fuel price has virtually no impact on the renewable abatement potential and the cap. The cap at the end of the second CRC phase under a carbon price of £500/ tCO2 and central fuel prices is 40.3 $MtCO_2$ and under high fuel prices is 40.2 $MtCO_2$.

Table 18 Cap by fuel price for 2017 and 2022

Cap year	Fuel prices	BAU Emissions (MtCO2)	Cost effective efficiency abatement potential* (MtCO2)	Cap excluding renewables (MtCO2))	Renewables** (MtCO2)	Cap including renewables (MtCO2)	Reduction from BAU (%)
2017	Low	75.0	16.0	59.0	0.1	58.9	21%
2017	Central	75.0	16.0	59.0	0.1	59.0	21%
2017	High	75.0	16.1	58.9	0.1	58.8	22%
2022	Low	77.0	23.2	53.8	1.4	52.3	32%
2022	Central	77.0	23.3	53.6	1.4	52.2	32%
2022	High	77.0	23.4	53.5	1.4	52.1	32%

Notes: *Efficiency abatement potential from energy efficiency measures only - excludes renewable electricity and heat; ** Renewables includes renewable electricity and heat. Source: SKM Enviros, Ecofys, Entec UK (2010)

10.6.4. Sensitivity of cap to technology penetration rate

Table 19 shows the variation in cap for a range of technology penetration rates. All other parameters are unchanged from the CCC Central scenario.

The modelled cap was sensitive to altering the assumed penetration rates of abatement technologies from low to max (see section 8.4 for details of low, central and max). The energy efficiency abatement potential in 2017 for the 'Low' technology uptake scenario is 26% less than that for the

CCC Central (with 'Central' technology uptake) and is 42% higher than 'Central' for the 'Max' technology uptake scenario. At 2022 there is slightly less sensitivity because by that date the majority of measures modelled have been taken up under the Central scenario.

Table 19 Cap by technology penetration rate for 2017 and 2022

Cap year	Technology penetration rate	BAU Emissions (MtCO2)	Cost effective efficiency abatement potential* (MtCO2)	Cap excluding renewables (MtCO2)	Renewables** (MtCO2)	Cap including renewables (MtCO2)	Reduction from BAU (%)
2017	Low	75.0	11.9	63.2	0.1	63.1	16%
2017	Central	75.0	16.0	59.0	0.1	59.0	21%
2017	Max	75.0	22.7	52.3	0.3	52.0	31%
2022	Low	77.0	20.5	56.4	1.1	55.3	28%
2022	Central	77.0	23.3	53.6	1.4	52.2	32%
2022	Max	77.0	25.4	51.6	1.3	50.3	35%

Notes: *Efficiency abatement potential from energy efficiency measures only - excludes renewable electricity and heat; ** Renewables includes renewable electricity and heat. Source: SKM Enviros, Ecofys, Entec UK (2010)

10.6.5. Sensitivity to BAU growth factor

Table 20 shows the variation in the cap using different BAU growth rates. All other parameters are unchanged from the CCC Central scenario.

For the CCC Central scenario we used DECC's LCTP energy projections 'Central scenario' for GDP growth and BAU changes in energy efficiency. These are sector specific i.e. for the public, industry and commercial sectors These Central scenario BAU growth projections involve more than simply GDP growth assumptions, see section 8.3. Using these projections, the BAU emissions projections show slow growth in emissions in the early years (influenced by the recession). Under the DECC Central scenario the baseline emissions in 2017 are equal to emissions in 2009 and have only grown slightly (by around 3%) by 2022[54].

We have examined the impact of increasing the year-on-year growth rates of carbon emissions under BAU to 1% and 2% per year (using the same rate for each of the three sectors – commercial, industry and public). At a 2% annual growth rate the BAU emissions increase by 22 $MtCO_2$ by 2022 relative to the baseline year; this is very close to the energy efficiency emissions abatement potential over this period (24 $MtCO_2$). Hence the cap in 2022 (72 $MtCO_2$) is approximately equal to the 2009 baseline emissions of 75$MtCO_2$ and, is in effect requiring no growth in emissions between the base year of 2009 and 2022.

[54] The DECC Central BAU growth projections are broken down approximately to 0.5% growth year on year; http://www.decc.gov.uk/en/content/cms/statistics/projections/projections.aspx

Table 20 Cap by BAU growth factor for 2017 and 2022

Cap year	Growth factor	BAU Emissions (MtCO2)	Cost effective efficiency abatement potential* (MtCO2)	Cap excluding renewables (MtCO2)	Renewables** (MtCO2)	Cap including renewables (MtCO2)	Reduction from BAU (%)
2017	Central	75.0	16.0	59.0	0.1	59.0	21%
2017	1%	80.4	16.2	64.1	0.1	64.0	20%
2017	2%	87.8	16.4	71.4	0.1	71.3	19%
2022	1%	84.5	23.6	60.9	1.4	59.5	30%
2022	Central	77.0	23.3	53.6	1.4	52.2	32%
2022	2%	97.0	23.8	73.1	1.4	71.7	26%

Notes: *Efficiency abatement potential from energy efficiency measures only - excludes renewable electricity and heat; ** Renewables includes renewable electricity and heat. Source: SKM Enviros, Ecofys, Entec UK (2010)

10.6.6. Sensitivity to CRC threshold

Table 21 shows the variation in cap according to different CRC thresholds. All other parameters are unchanged from the CCC Central scenario.

Lowering the CRC inclusion threshold from 6,000MWh to 3,000MWh resulted in an additional 7 $MtCO_2$ emissions by 2017 for the BAU emissions relative to the CCC Central scenario. Under the 3,000 MWh threshold the energy efficiency abatement potential increases by 2 $MtCO_2$ by 2022 – in percentage terms the efficiency abatement potential remains constant (21% in 2017 and 30% in 2022). These changes from the CCC Central scenario (with 6,000 MWh threshold) result in the cap increasing from 52 $MtCO_2$ to 57 $MtCO_2$ under the 3,000 MWh threshold scenario.

The scenario analysis does not take into consideration the proportion of energy efficiency opportunities available to smaller organisations in comparison to larger organisations. Carbon Trust has found that energy savings may be proportionately higher for smaller sized organisations in comparison to larger organisations.

Table 21 Cap by CRC threshold for 2017 and 2022

Cap year	CRC threshold (MWh)	BAU Emissions (MtCO2)	Cost effective efficiency abatement potential* (MtCO2)	Cap excluding renewables (MtCO2)	Renewables** (MtCO2)	Cap including renewables (MtCO2)	Reduction from BAU (%)
2017	3,000	82	17.6	64.4	0.1	64.3	22%
2017	6,000	75.0	16.0	59.0	0.1	59.0	21%
2022	3,000	84.1	25.6	58.6	1.4	57.2	32%
2022	6,000	77.0	23.3	53.6	1.4	52.2	32%

Notes: *Efficiency abatement potential from energy efficiency measures only - excludes renewable electricity and heat; ** Renewables includes renewable electricity and heat. Source: SKM Enviros, Ecofys, Entec UK (2010)

10.7. Renewable Heat Abatement Potential

10.7.1. Contribution of carbon savings from the Renewable Heat Incentive (RHI) for the CRC sector

The RHI will reduce the overall costs for implementing renewable heat and hence it is expected that an additional quantity of renewable heat will become cost-effective to undertake for the CRC sector. DECC's RHI Impact Assessment states that the cost effective threshold for renewable heat measures with the application of the RHI is £75/MtCO2. Given that the cost effective threshold for the NERA heat model MACCs can be assumed as currently being £0/MTCO2, the additional cost-effective renewable heat potential that can attributed to the RHI can be read as the difference in the renewable heat potential available at £0/MtCO2 compared to at £75/MtCO2.

The greatest impact is seen for the public sector, where around an additional 10% of the total heat MACC becomes cost-effective to undertake. The impacts for the commercial and industrial sector are an order of magnitude less than for the public sector – for the commercial sector, the additional potential is small; for the industry sector, the additional potential is insignificant. Note that while the additional potential from the RHI under NERA's maximum technical scenario is substantial for all three sectors; this is not reflected in the high, medium or low scenarios in the NERA model.

10.7.2. RH competitiveness with energy efficiency under the RHI

Despite the cost-effective potential for renewable heat under the RHI moving from £0/tCO2 to £75/tCO2, renewable heat measures may not become competitive with energy efficiency measures for two reasons:

- Energy efficiency measures at £0/tCO2 combined (according to N-DEEM and ENUSIM) offer a greater abatement potential than renewable heat measures combined at £75/tCO2 – hence for the same effective cost, the consumer will see more abatement with energy efficiency than with renewable heat.
- Even if some renewable heat measures become more cost effective than some energy efficiency measures with the application of the RHI, other barriers to the uptake of renewable heat (such as inertia, level of market familiarity with renewable heat, market acceptance of renewable heat hidden costs) will come into play and would be expected to impact on the uptake of renewable heat to a greater extent than barriers to the uptake of energy efficiency.

10.8. Renewable electricity abatement potential

As outlined in section 8.4.3 it was not possible to split the amount of savings between the CRC and FITs because the background FITs study was based on national figures and there is not enough information to be able to extract the necessary data on non-domestic CRC buildings.

At £14/tCO2 (CRC safety valve) and £12/tCO2 (CRC allowance price in the introductory phase) the value to be gained through FITs for a certain amount of electricity generated will likely be greater than the cost of a CRC allowance at either price. It is therefore likely that the majority of savings from renewable electricity can be attributed to FITs and that only a small part can be attributed to CRC.

This was the reason for building the modelling tool to show a cap estimate for 'with' and 'without' renewable. If the treatment of FITS within the CRC is the same as ROCs then broadly any electricity generated from renewable plant in receipt of FITs will be reported under the CRC using the grid emission factor. The reported emissions would therefore be the same as if no renewable plant had been installed. For the policy as it stands, the cap should be based on reported emissions without renewable electricity.

10.9. Qualitative Assessment of Key Uncertainties

The key uncertainties around the model outputs shown above are:

- Coverage of the CRC subsectors: there is currently a lack of accurate data on the emissions that will be covered by the CRC. Energy consumption data on most of the CRC sectors is over 7 years old and estimates of emissions and coverage vary, see section 5. For this modelling CRC coverage has been estimated based on a number of sources coupled with expert judgment on the extent of coverage, see section 7.5. This problem will diminish in summer 2011 when the first set of actual reported consumption figures from CRC participants becomes available and again in July 2012 when the second set of actual data is reported.
- Lack of updated data and sufficient level of granularity for CRC sectors in ENUSIM and N-DEEM: the two models that underpin the outputs of this study are not suitable tools for assessing emissions and abatement potential of CRC subsectors. The MACCs generated by the two off-models of ENUSIM and N-DEEM are based on data which for ENUSIM has a high level of granularity of measures but better represents CCA sectors than CRC sectors and for N-DEEM does not have the necessary level of detail. Also, the data does not seem to include the full range of abatement technologies that are available to the CRC subsectors. As a result the MACCs which were used in this study appear to be missing a significant amount of energy efficiency abatement potential at costs above £0/tCO_2. This explains the lack of sensitivity of the cap to variation in the carbon price, discount rate and fuel price.
- Lack of time line for implementation of the abatement potential represented by the MACCs: the projected rate at which technologies will be implemented is a key determinant of the projected abatement potential that will be realised by the end of each of the 5-year periods and consequently impact the cap which will need to be set on an annual basis. The available MACCs do not provide information on the rate of implementation.
- Growth in emissions under BAU: there is a huge uncertainty around the projected growth in GDP and economic activity which underpin the BAU emissions trajectory i.e. what will actually happen to the BAU emissions trajectory. Even a modest positive year-on-year growth in the BAU emissions (e.g. 2%) will offset most of the CRC cost-effective abatement potential thereby resulting in a minor change in emissions from the baseline year through to the end of the CRC period.
- Fuel prices: fuel prices are extremely volatile and uncertain yet have a significant impact on the payback of abatement technologies and renewable energy. Any assumptions made on the fuel prices should have a significant impact on the uptake of abatement technologies and hence on the cap (although the current Enusim and NDEEM modelling seems insensitive to such changes, see earlier in this section and section 6).

Other sources of uncertainty are:

- Estimating the realistic abatement potential: the proportion of the technical abatement potential that can realistically be achieved depends on various assumptions related to the extent that different financial and non-financial barriers can be overcome. It is currently unknown whether and to what extent the CRC financial and reputational drivers will facilitate a quicker and higher level of uptake of technologies.
- Renewable energy and interaction with other policies: there is a considerable uncertainty around the available renewable electricity and heat abatement potential which could be realised by the CRC sectors. The CRC aims to promote energy efficiency as the main driver of emissions reduction but renewable energy could also contribute to the CRC cap. It is currently unclear to what extent financial incentives for renewable electricity and heat, such as FITs, might drive CRC participants to meet their emissions reduction targets through primarily renewable electricity and heat instead of energy efficiency. See earlier in this section for discussion on the contribution of the RHI and FITs to the CRC cap. Government will need to decide how to take this into account, even if other policy mechanisms are driving the uptake of renewable. It is also unclear to what extent the abatement potential of the CRC will interact/ overlap with that of other energy efficiency policies.

10.10. Conclusions

The purpose of this study is to explore different options for setting the CRC cap. This is extremely important for the success of the CRC scheme. If the cap is set too high then the abatement potential of the scheme will not be achieved and the emissions targets will be missed. If the cap is set too low then the participants may endure higher than acceptable costs which may ultimately damage both participants and the reputation of the CRC.

The results in section 10 were generated using a computer model which estimates the cap by subtracting an estimated cost-effective abatement potential from projected BAU emissions. The abatement potential and BAU emissions are estimated by the model based on a series of assumptions which can be modified by the user of the model.

Under the CCC Central scenario the annual BAU emissions for the period up to 2022 are projected to be around 77 $MtCO_2$, the cost-effective abatement potential (£0/tCO_2) at around 23 $MtCO_2$ and the cap including renewables for 2022 at around 52 $MtCO_2$.

The model was then used to explore how the cap at the end of the first period (2017) and second period (2022) might change in response to variation in different parameters including: carbon price, discount rate, fuel prices, technology penetration rates, growth rate and the CRC inclusion threshold.

Overall, the model showed some sensitivity to variation in penetration rates and growth rates but very little sensitivity to variation in the other parameters investigated. The cost-effective and total energy efficiency abatement potential remained almost constant regardless of the parameter varied. As expected, renewable energy potential was available only at costs above £0/tCO_2 but the amount of that potential was not sensitive to changes in fuel prices or discount rate. Lowering the CRC inclusion threshold from 6,000 to 3,000MWh resulted in an increase in the BAU emissions (due to greater policy coverage) and a proportional increase in abatement potential. The use of strong growth rates in the BAU emissions (2% year-on-year) could almost entirely offset the cost-effective abatement potential hence resulting in a cap similar to the baseline year.

There are several reasons for the model's lack of sensitivity to these parameters. The MACCs used by the model are based on the ENUSIM and N-DEEM off-models which are not appropriate for assessing the CRC cap. The data within ENUSIM and N-DEEM has not been updated for the CRC subsectors and there is a lack of sufficient information on the suite of abatement technologies relevant and available to these CRC subsectors. These issues contribute to the uncertainty around the modelled cap and we strongly recommend these are addressed by Government.

Other sources of uncertainty around the cap are associated with estimations of: CRC coverage (this will be solved next year when real data will be available), abatement potential, fuel prices and growth rate in BAU emissions. Section 12 outlines how the uncertainty might be resolved.

More detailed studies may be required to investigate such policy overlaps before the cap is finally set. In this context, it is important to learn lessons from the EU ETS and UK ETS experience – these schemes have over allocated emissions resulting in a crashing carbon price and high emissions, see section 12. Domestic action on energy efficiency and carbon savings through the setting of the CRC cap must underpin the carbon price in the short term.

11. Incentivising energy efficiency

11.1. Introduction

Delivery of the cap once set will be crucial to the UK achieving its national absolute carbon emissions reductions targets. Barriers and market failures mean that cost-effective abatement measures are not being taken up in the target CRC sectors, in which energy costs represent a relatively small proportion of total costs. The CRC's objectives are to encourage carbon savings within large organisations, primarily by driving uptake of cost-effective end use energy efficiency measures and fuel switching – in order to help the UK meet its medium and longer-term greenhouse gas emission reduction targets. Without Government intervention, meeting the UK targets would be more costly, as the cost-effective abatement identified by analysis would not be realised.

This section provides a qualitative examination of the measures that could be used to incentivise or enhance emissions reductions amongst the CRC population. It is structured as follows:

- section 11.2 summarises the energy efficiency measures for which barriers were explored;
- section 11.3 outlines the barriers facing CRC sectors;
- section 11.4 discusses the range of measures that could be used to incentivise or enhance emissions reductions amongst the CRC population, including the associated pros and cons, in light of the timescales, objectives of the CRC and other policies already in place, and provides a high level assessment of the impact that the measures would be expected to have (e.g. whether they would speed uptake or influence it in another way, and how big an impact this could have (high, medium, low); and,
- section11.5 provides concluding remarks.

This review used interviews with the Local Government Information Unit (LGIU) and energy efficiency experts working with certain CRC sectors[55].

[55] e.g. buildings/ offices, public sector (NHS and local authorities), food and drink (light industry), lighter industry outside of CCAs and EU ETS

11.2. Energy Efficiency Measures Considered

This assessment concentrated on establishing the barriers to implementing energy efficiency measures associated with energy end use categories such as space heating and lighting which may have efficiency measures applied to them. This does not therefore include renewable heat or electricity.

The list of energy efficiency measures includes:

- monitoring and targeting
- behaviour change
- insulation
- lighting e.g. new efficient light sources, controls
- space heating e.g. building energy management, boiler efficiency measures
- boilers e.g. replace steam boilers with CHP, renewable heat
- motors, pumps and compressed air
- waste heat recovery
- maintenance e.g. fouling mitigation
- refrigeration and air conditioning
- ventilation
- domestic hot water

11.3. Main Barriers and Sectoral Differences

The main barriers to implementing energy efficiency measures facing all CRC sectors are:

- financial;
- disruption created by retrofitting;
- lack of knowledge including lack of awareness of technology and lack of trained engineers; and,
- conflicting priorities within organisations.

The barriers experienced by individual sectors are:

- least for private sector offices and hotels (just financial and time resource barriers);
- greatest for light industry (experts cited the most barriers for this sector in comparison to the other sectors);
- similar for the food supply chain industry and the NHS: the main barriers are financial resources, payback time and conflicting priorities but to varying degrees. The NHS

experiences greater hassle and difficulty retrofitting energy efficiency measures, with an additional barrier due to political issues.

- slightly different for local authorities in comparison to the NHS, including a lack of awareness of energy efficiency measures and resistance to behaviour change.

The results from the interviews spanning five CRC sub sectors are summarised in Appendix H.

11.3.1. Financial resources

Financial resources were seen as the largest barrier to implementing energy efficiency measures in every sector. Due to economic uncertainty, short term financial planning in the private sector does not allow consideration of measures with a payback beyond three to five years. NHS Trusts are also limited to shorter term planning and payback time below five years. Each year NHS Trusts are under pressure to meet financial targets and money ring fenced for energy efficiency investment is often spent on general running costs as budgets run tight at the end of the year. Time resources and hassle were also major barriers as energy efficiency is often added to the job description of overloaded utility managers and environmental managers.

11.3.2. Disruption to everyday activities

The disruption to everyday activities is a major barrier to retrofitting energy efficiency measures. For example for an NHS Trust, boiler replacement means evacuating a whole hospital ward, and a large scale lighting refit would involve emptying an office for a week. Barriers due to lack of knowledge were common across most sectors (lack of awareness of technology, lack of trained engineers). Conflicting priorities within the organisation were also seen as a significant barrier, but it is hoped that the CRC will force energy efficiency up the agenda of board meetings as it is intended the policy will do so.

11.3.3. Lack of awareness and knowledge, and poor data

Monitoring (through sub metering and data recording) and targeting (through analysis) (M&T) underpin carbon saving programmes within organisations and enable energy savings from better management of space heating and behaviour change initiatives to be tracked. The vast majority of organisations that will be captured by the CRC do not have M&T in place due to a lack of awareness of the benefits, and a lack of time and ownership to make the case for implementation.

Space heating control improvements and boiler efficiency measures were seen as having the most carbon saving potential in every sector. Although improvements to space heating management are often overlooked due to lack of maintenance and knowledge, there are very few real barriers to prevent action.

New efficient light sources and controls were viewed as having a strong potential for uptake across all sectors. Barriers included lack of knowledge of the fast moving technology developments, a lack of trust of lighting controls and safety considerations in the NHS and longer payback times for the more advanced technology.

A lack of tailored, up to date information on technologies was seen as a barrier to additional uptake of lighting technologies, voltage optimisation, M&T and space heating control amongst others.

The Local Government Information Unit (LGIU) confirmed additional barriers to those listed in Appendix H. For the public sector as a whole, barriers to implementing energy efficiency measures also include:

- a lack of data of sufficient quality e.g. for all energy use and on the basis of building occupancy;
- the impact of ‘special events’ on energy use e.g. a colder than average winter; and,
- a lack of understanding of the importance of energy efficiency and of the impact of carbon pricing.

11.4. Incentives to Energy Efficiency Uptake

There are two elements to incentivising energy efficiency uptake: first, whether or not CRC participants can be incentivised to ensure delivery of, and beyond, the cap; and second, if/ how an organisation which does not want to take action to reduce its energy use might be incentivised differently to an organisation which may be unable to reduce its energy use.

It is not possible to differentiate between incentives to ensure delivery of the cap and to potentially enhance the estimated savings. Whether or not the cap is delivered by CRC participants or the amount of carbon savings achieved is beyond the cap will depend on a range of variables including what the cap is set at and the extent of energy efficiency measures already used/ implemented by an organisation.

It is likely that there will be both types of participants in the CRC i.e. those which do not wish to take action to reduce energy use (and can afford to buy as many carbon allowances as required) and those which are unable to take action to reduce their energy use.

The majority of incentives suggested by experts would be available to both types of organisations if desired. It was suggested however that those organisations that are unwilling to take action would not be helped by additional or different types of incentives.

The incentives listed below concentrate on helping to expedite and widen the uptake of energy efficient measures in the sectors affected by the CRC. The focus was on how to incentivise energy efficiency implementation in organisations where CRC does not sufficiently motivate them to reach their cost effective abatement potential.

The main incentives suggested concentrated on:

- tailored information and guidance;
- improving accessibility to loans;
- ring fencing CRC revenue for more sustained carbon management support;
- funded monitoring and targeting programmes;
- changes to contract terms for managed buildings; and,
- financial mechanisms to provide a more secure return on investment in energy efficiency measures.

A summary table of the incentives suggested is provided in Appendix H.

11.4.1. Tailored information and guidance

The provision of tailored information and guidance was the most commonly suggested measure to address the barriers to uptake of lack of understanding and awareness of technologies and to give more confidence to companies to invest in technologies, particularly in rapidly evolving technologies such as lighting and voltage optimisers. If supply chain links to the CRC sectors strengthen and bulk purchasing takes off, e.g. voltage optimisation is becoming more popular with local authorities, supply costs may also come down. A high impact on energy saving may therefore be achievable if a major commitment was made to generating information to sufficient quality (tailored to each sector with practical examples, guidance and recognition of difficulties facing that sector, up to date, costed) and quantity (ranges of technologies and applications to the full range of CRC sub sectors).

Barriers due to lack of knowledge were common across most sectors (lack of awareness of technology, lack of trained engineers) and these could be addressed by policies on information provision, engineer training and/ or industry body affiliation requirements.

11.4.2. Improve accessibility to loans

Improving the accessibility of loans for energy saving technologies was suggested. Current loan application processes are time intensive and it was commented that this was a deterrent, particularly on the Salix loan scheme. A more straightforward process should speed uptake, but would increase the risk of inadvertently funding projects with little additional carbon saving.

11.4.3. Ring fence CRC revenue

One of the experts interviewed suggested that ring fencing CRC revenue for intensive carbon management support was a strong incentive. This was requested by stakeholders in each of the CRC consultations.

Less than half of the energy efficiency recommendations currently made under Carbon Trust funded carbon management support are implemented. If more funding was available through ring fencing CRC revenue, a more intensive and longer term (over a period of years) carbon management support service could be offered to help organisations implement a larger number of energy and carbon saving projects.

The auction revenue in the introductory phase is likely to be approximately £638 million per year if the CRC target group of organisations emissions are 53.2 $MtCO_2$ PA[56] and the allowance price is £12/tCO_2. Ring fencing 10% of this auction revenue would provide a reserved fund of £63.8 million per year, which the target group could access through requesting, for example, an intensive and long term carbon management programme or to provide support and capital grants for M&T. If each of the 5,000 organisations in the CRC Target Group requested funding from this fund, it would amount to £12,800 per organisation; therefore some prioritisation process would be needed if larger scale support packages were to be offered. For comparison, the Carbon Trust offered £22.3 million in interest free loans to help 700 businesses invest in energy efficient equipment in 2008/09[57]. The Carbon Trust predicts this will lead to total savings of 0.06 $MtCO_2$ annually.

Although ring fenced revenue could provide access to capital grants and focus and support to CRC organisations, there are barriers at a number of levels, which include:

1) Potential objections from the Treasury, for example, the scheme is less clearly revenue neutral and is less transparent and more complex to administer;
2) CRC organisations may object as they will get less direct cash in hand back to cover allowance costs, and there will be some winners and some losers who fail to get allocated funding;
3) It would add an additional source of public sector funding for energy efficiency measures and could duplicate Salix, Carbon Trust and EST activities.

11.4.4. Funded M&T programmes

Every sector expert felt there was a major lack of monitoring and targeting of energy use. One of the fastest ways to address this would be to fund M&T programmes, making capital available for metering equipment and support in using the data, combined with support measuring impacts of behaviour change initiatives. Lack of awareness of the benefits of M&T is so great that it was felt that guidance alone would not fill the gap. As mentioned above, if a percentage of CRC revenue was ring-fenced, monitoring and targeting should be a priority for funding.

[56] Final Impact Assessment on the Order to implement the CRC Energy Efficiency Scheme, DECC, 2009
[57] Driving Action Now and In the Future, Annual Report 2008/09, The Carbon Trust

11.4.5. Tighter contract terms and tailored guidance

With the increase in the sub contracting of public sector activities to private companies such as the management of leisure centres and MOD estate management, the government has less and less control over the energy saving measures and maintenance in these buildings. Tighter contract terms are needed to lay out responsibilities for energy efficiency to ensure privately managed buildings (where the energy bill is still paid by the government) contribute to meeting public sector carbon targets. Tailored guidance on who is exposed to the risk of CRC and who is actually in control of saving the carbon will help this process.

11.4.6. Grants, cost of carbon, secure benefits for technologies

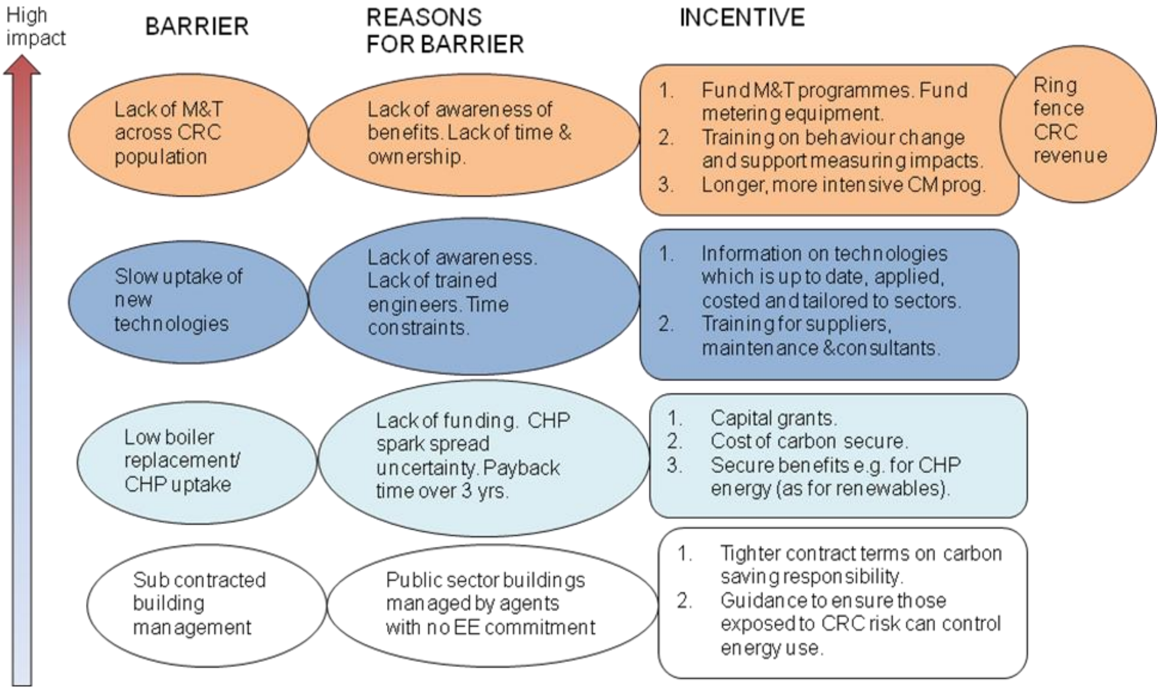
Comparisons were made between the financial incentives available for renewable technologies and energy efficient technologies, with the conclusion that more could be done to fund energy efficiency measures. Suggestions included providing grants for energy efficient technologies, setting a constant cost of carbon to provide security for investment, providing secure benefits for technologies such as non-renewable CHP (renewable CHP is covered by FITs under the RHI) and reducing payback time to under three years (e.g. funding that is heavily weighted to the first year after installation). All of these measures are more difficult to justify - each would require major fiscal support at a time when the Government is entering a period of shrinking public sector spend.

11.5. Conclusions

CRC sectors face a range of barriers to implementing energy efficiency measures. This latest view of barriers to energy efficiency for the CRC sectors is supported by previous work to assess barriers for the CRC sector (NERA, 2006). There are some similarities and some differences between those experienced by the public and private sectors, see section 11.3. A range of incentives has been suggested, with funding a monitoring and targeting programme likely to have a high impact on delivering energy savings. The LGIU commented that the delivery agent of incentives is key to delivery of energy savings. It has not always been clear for example which organisations provide advice for which CRC sectors. As a consequence of this certain public sector organisations have put off implementing energy efficiency measures.

Finance, staff time and lack of awareness were the most significant barriers to energy efficiency uptake cited in our expert interviews, so a high profile ring fenced fund for energy efficiency support and measures could go a long way to addressing these three issues. To make a maximum and sustainable impact on carbon saving, freeing up capital to fund M&T programmes, metering equipment and longer more intensive carbon management programmes will make the biggest difference to the CRC population. There is no quick fix to going beyond cap savings, and the cap alone is unlikely to motivate M&T activities, so this combined package of support based on ring fenced CRC revenue is likely to make the most difference. However, the significant barriers to ring-fencing from central government and CRC organisations themselves are still apparent and so other measures to speed technology uptake such as comprehensive up to date information sheets on technologies could play an important role.

- **Figure 5 Incentives to overcome barriers and speed energy efficiency uptake, rated by impact**



Source: SKM Enviros, Ecofys, Entec UK (2010)

12. How CCC Can Recommend a Cap

12.1. Introduction

The modelling for this project improves on previous understanding of CRC sectors and the assessment of abatement potential available to CRC sectors. It is based on existing datasets and models in order to analyse the CRC cap for the first and second capped phases. As described in previous sections, there remain some significant limitations to the modelling and the cap estimates produced under a series of scenarios. For the modelling this is primarily the lack of specificity to the CRC both in terms of participants and their corresponding abatement opportunities and savings potential. For the cap estimates these limitations are highlighted mainly through the insensitivity of the outputs to key parameters such as fuel and carbon prices.

The next step is to address how this work can help CCC to provide guidance to Government on setting the CRC cap and recommend values for the CRC cap.

This section is structured as follows:

- section 12.2 provides details of the key uncertainties and information gaps identified during this research i.e. the context of the cap estimates provided by this modelling;
- section 12.3 recommends the next steps for CCC and Government and presents options for building on this analysis, both as further actual data is available once the CRC is in operation, and also given extra time to improve some underlying assumptions;
- section 12.4 discusses some lessons learned from other emissions trading systems to be considered in cap setting for the CRC.

Any future work undertaken to help CCC to provide guidance to Government will need to take into consideration ongoing and related work such as: the study assessing the emissions and abatement potential for organisations not covered by EU ETS, CCAs or CRC (i.e. small-medium enterprises (SMEs); and, recent work completed to update ENUSIM. This was done on a whole-of-sector basis i.e. including the CRC and non-CRC portions of the CCA sector but was not specifically updated for the CRC sectors.

12.2. Key Uncertainties and Information Gaps

Taking into consideration the CRC cap setting requirements discussed in section 6, the insensitivities of the results to key parameters, this work has highlighted some important uncertainties and information gaps around the cap estimates and therefore potentially for any cap which is to be set for the CRC. These are set out in Table 22.

Table 22 Summary of key uncertainties and information gaps

Issue	Headline issue	Uncertainty	Information gap	Recommendations
1	Coverage of the CRC sectors and subsectors	Base year emissions starting point of CRC participants including intra- and inter-sectoral differences	Accurate energy use data for all sectors and subsectors including for electricity and heat use	Initially use improved estimates in this study, but ensure that actual cap set via use of real data from CRC participants
2	Understanding of impact of policy changes on CRC coverage	Example: extent of CCA and EU ETS emissions exclusions	Accurate energy use data for all sectors and subsectors	Use real participant data to understand extent of coverage and exclusions
3	Suitable tools for assessing CRC emissions and abatement potential	Accuracy of cap estimates derived from non-CRC specific off-models of ENUSIM and N-DEEM	Updated and comprehensive abatement potential data on which to base new and CRC specific modelling	It is essential to base cap estimates on improved CRC-specific modelling
4	Timeline for implementation of abatement potential represented by MACCs used	Rate at which technologies in current modelling will be implemented	Market penetration and uptake rates of technologies Cross referenced with accurate energy use data for all sectors benchmarked and normalised to building type, information on trends in ICT and building stock condition Up to date building energy use benchmarking guidelines	New modelling must address the likely rate of take up of key energy efficiency technologies
5	Abatement potential misses out CRC sector specific technologies and quantities of abatement potential	Extent to which there are technologies missing and corresponding volumes of abatement potential	Additional technologies and corresponding volumes of abatement potential per CRC sector/ and subsector	Can be addressed by new modelling
6	GDP growth and economic activity will impact on the CRC BAU emissions trajectory	Nature of GDP growth and economic activity and impacts on CRC BAU emissions trajectory	Supporting information to accompany and cross-reference with DECC energy projections e.g. market status reports for individual sectors	Use flexible growth factors in the CRC spreadsheet tool delivered with this study to test a range of scenarios

Issue	Headline issue	Uncertainty	Information gap	Recommendations
7	Fuel prices are extremely volatile and uncertain	Unknown impact of fuel prices on the uptake of abatement technologies and renewable energy, hence on the cap, because the modelling for this project seems insensitive to such changes	New and CRC specific modelling which combines the above	Can be addressed by new modelling
8	Response to CRC drivers	Extent to which CRC financial and reputational drivers will be successful in driving energy efficiency uptake is unknown Proportion of the technical abatement potential that can realistically be achieved is therefore unknown	Sectoral specific data on nature of barriers to energy efficiency uptake cross-referenced with high level sectoral information on market penetration data, see above	Ensure development of incentives and supporting policies considers latest literature on barriers
9	Renewable heat and electricity uptake	Extent to which available renewable electricity and heat abatement potential could be realised by CRC sectors Extent to which financial incentives such as FITs and RO might drive CRC participants to meet emissions reduction targets through renewables instead of energy efficiency	See 3, 4 and 7 above	More clarity needed about rules for handling renewables (to avoid double counting of savings). Some CRC specific renewables modelling may be required.
10	Interaction with other policies	Extent to which CRC abatement potential interacts/ overlaps with that of other policies e.g. RO and FITs	Modelling which takes into consideration the interactions of abatement potential earmarked for different policies	Modelling needs to assess overall emission reduction potential. Subsequent analysis can address which policies will deliver this potential and how this should be reflected in the cap set.

Source: SKM Enviros, Ecofys, Entec UK (2010)

12.3. Enabling CCC to Recommend a Cap: Next Steps

12.3.1. Base year emissions and participant data collection

This work provides an improved understanding of the CRC sectors and appropriate groupings, see section 7. We recommend that the CCC recommends to Government that the EA begins to use this more appropriate grouping of CRC participants (guided by SIC code and participant reporting) for collecting information from participants to identify which sectors and subsectors they are active in. This will provide the split of energy use between sectors and subsectors.

While understanding of total and CRC sectoral base year emissions has been improved through this work, CCC should not recommend an absolute CRC cap without real base year data. By summer 2012, there will be two years' worth of real data available from annual footprint reports from all CRC participants. An absolute cap or target can be finalised at this point.

This real data will meet several of the main requirements outlined in section 6.2.1:

- total baseline coverage;
- split of energy use between sectors and subsectors (if collected as described above); and,
- split of energy use between electricity and fossil fuels ('heat' has been used throughout project discussions as a shorthand for fossil fuels)

An organisation's data will be acknowledged to one specific address so the actual data will not provide an accurate base year emissions split by DA or where organisations 'span' a number of sectors but report a single data set. This issue would be very difficult to address now. We recommend instead that the EA requests for participants to complete a questionnaire with their first annual reports:

- giving estimates of the proportions of their organisation's total emissions within each of the DAs: questionnaires could be customised to high level organisation type e.g. local authorities, supermarkets etc;
- describing the sectors in which they operate including e.g. a approximate split of energy used in each sector.

The design of a questionnaire would need to be done carefully to maximise the usefulness for analysing such elements as sector and DA splits. In autumn / winter 2010 an analysis of the actual participants that have registered for the CRC could then be done.

We do not recommend any further research on the total and CRC sectoral base year emissions.

CCC should recommend that the EA assesses the robustness of participants' real energy use data available in July 2011 and July 2012. This could be done through a comparison of the proportion of estimated data reported versus actual data in footprint and annual reporting. Year 2 data available in July 2012 could be compared to July 2012 in the same manner. Building energy use benchmarks could be used to inform the verification/ audit process to be conducted by the regulators which would help to make a judgement on the robustness of the actual reported data.

12.3.2. CRC specific abatement modelling

This work provides an improvement on previous CRC carbon savings estimates through:

- the selective mapping of ENUSIM sectors to CRC sectors;
- the segregation of ENUSIM and N-DEEM technologies into four groups to enable differentiated uptake rates to be applied to them; and,
- the use of relative rather than absolute abatement potentials.

Despite these improvements to CRC abatement modelling there remains some limitations. A set of prediction tools is required which enables the accurate modelling of the total emissions and abatement potential available for all CRC participants. It is strongly recommended that the CCC and DECC take a fundamental look at the requirements described in section 6.2.1 in conjunction with the information gaps identified to ensure that any future modelling work is fit for purpose from a CRC perspective. New modelling would provide another view on the cap outputs from this modelling. We recommend grouping participants as outlined in section 7.

Use of existing models and new modelling approaches

Options for developing modelling tools[58] to reflect more accurate sensitivity to key drivers and a more comprehensive view of CRC specific abatement are as follows.

Option 1: Improve the ENUSIM model. ENUSIM has a powerful calculation engine but it is implemented with a very complex data structure. It may be possible to use it with a simpler data structure and take advantage of the engine or implement the basis of the engine within another tool. It would need considerable research into CRC specific abatement technologies, but could be used for improved bottom up modelling. (N-DEEM is not appropriate for future modelling. It does not exist in a format that can be interrogated or re-run and there is no longer sufficient N-DEEM expertise available to support attempts to do so.)

[58] To use the outputs of any improved modelling with the modelling for this project, CCC would need to format the new material to act as 'core calculation worksheets' for the spreadsheet modelling provided for this project

Option 2: Develop a new modelling approach suited to CRC sectors. A new approach based on evaluating key categories of energy use for CRC participants could provide a more effective, flexible and transparent modelling tool. This would involve:

- Defining key categories of energy use e.g. lighting, ventilation, air-conditioning etc.
- Allocating electricity and heat use in each modelling sector e.g. supermarket electricity = 40% refrigeration, 15% air-conditioning, 25% lighting, 10% IT, 10% ventilation (approximate figures)
- Creating "technology MACCs" for each energy use category e.g. lighting sources
- Building an overall MACC for each modelling sector, using appropriately weighted technology MACCs

This approach could be implemented taking into account the likely rate of take up of measures, which is a vital input into the setting of an annual cap. A spin off benefit of this approach is that for each modelling sector the amount of saving potential for each technology category will be estimated. This information can be used as a basis for targeted energy efficiency advice that can be customised to each sector of CRC participants.

Option 3: Base cap on historic trends. A new more simplistic approach based on an 'annual reduction challenge' which would involve:

- Assessing historic trends (e.g. from CCA data for 10 years)
- Establishing challenging annual reduction rates

Option 4: Use models created in other countries. There are two types of models used internationally, detailed bottom-up models such as BEAM[59] or SERPEC-CC[60] and more top-down or hybrid models such as IDM used for US energy model[61] or the analysis developed by Fraunhofer for the Commission[62]. The model approaches could be used here but, even if a UK dataset is already included, it is likely that there will be similar problems to ENUSIM and NDEEM with applicability for the CRC sector.

Sectors to be modelled

The CRC sectors identified in section 7 should be used as the basis for new modelling. Most of the "heavy" industrial sectors with CCA and EU ETS exclusion consist of unrelated "fragments" and can be modelled as a single group. The engineering and water sectors remain as industry sectors that require improved sector specific modelling. The various non-domestic building sectors

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[59] Ecofys developed the BEAM (Built Environment Analysis Model). The model was used so far in more than 10 successfully executed projects (e.g. European Mineral Wool Manufacturers Association (EURIMA), German and French ministries, Manufacturers, Gas de France, European Commission etc.)

[60] http://www.ecofys.nl/com/publications/documents/SERPEC_executive_summary.pdf

[61] http://www.eia.doe.gov/oiaf/aeo/overview/industrial.html

[62] http://www.eepotential.eu/esd.php

require improved modelling at a suitable level of granularity e.g. supermarkets should be modelled separately from department stores and small shops.

Key data and elements for new modelling

It is vital that future modelling shows a realistic level of sensitivity to key economic factors such as discount rate, carbon price and fuel prices. The ENUSIM and N-DEEM outputs for this modelling show virtually no sensitivity to these parameters, see section 10. This suggests that the basis for this modelling is not appropriate rather than an actual lack of sensitivity in the cap to key parameters. To develop new modelling with more accurate sensitivity to key parameters there are key data and elements which would need to be researched and designed in.

- The "menu" of energy saving measures being analysed needs to be more comprehensive if we are going to pick up some sensitivity to carbon and fuel prices. The current modelling has a "restricted" menu of very cost effective measures – hence they are worth doing across a wide range of carbon and fuel prices. A more comprehensive menu would include extra measures that only become cost effective at high carbon or fuel prices.
- A good understanding is required of current and potential market penetration of all available energy efficiency technologies in key CRC sectors. Uptake rates could be informed in the future by targeting research at key CRC subsectors, to understand what technologies and abatement measures have already been implemented and are likely to be implemented in the near and far future. Information for the building sector might also be available through other sources such as for example the MTP programme and equipment suppliers.
- A further developed methodology for splitting abatement opportunities into groups with different uptake characteristics is required to estimate annual caps over 2 budget periods.
- A flexible technique for modelling potential technology change is desirable.
- A technique to model the extent of overlap between the CRC and other energy efficiency and renewables policies - to be able to update the estimated abatement potential of the CRC. More detailed studies may be required to investigate such policy overlaps before the cap is finally set. This would need to include research into the penetration and uptake of the full range of measures as above, and consideration of how the cap should be presented, see section 6.
- A technique to assess the impact of, and potential for, double counting of emissions savings from the same heat load: for example, the impact of installing insulation on the volume of savings then available from renewable heat measures. This project has not been able to make this assessment. Conversely if renewable heat is more cost effective then insulation is unlikely to take place. In terms of the measures in the modelling for this project all are very cost effective e.g. including insulation so organisations remain likely to implement these ahead of renewable heat measures.

- Future modelling will need to be able to evaluate the savings as a "time series" over the period for which annual targets are required and take into account influencing factors more adequately. Any potential new modelling will also need to offer a more dynamic cap setting analysis which will enable Government to analyse the annual caps which will comprise the 5-year CRC phases.

Data availability

Future data availability for these elements is uncertain and current data availability, on e.g. current energy efficiency technology penetration levels, restricted this modelling. To support how it recommends a CRC cap, CCC will need to recommend to DECC that such research is conducted in order to facilitate any of the above new modelling approaches.

12.4. Lessons Learned for Cap Setting

To enable the CCC to provide guidance on and recommend a cap the above areas will need to be discussed and developed alongside the following lessons learned from other trading system implementation.

12.4.1. Timing of initial cap setting

We recommend that the cap should not be firmly set until summer 2012 at the earliest. This would enable DECC and CCC to review data for the first and second years of the CRC (April 2010 to March 2011 and April 2011 to March 2012). Previous experience with CCAs and EU ETS shows that early data is not very accurate so basing the cap only on Year 1 CRC data is very risky.

One of the key reasons for Government's decision to operate the CRC with a 3-year introductory phase was to collect accurate baseline data that could be used for cap setting. This was recommended by Enviros/NERA in 2006.

CCC can however recommend an indicative % emissions reduction at a much earlier date - that will be of great help to CRC participants to inform their planning process. A % emission reduction figure should not be published on the basis of outputs from this project due to the modelling limitations already outlined in this report. To enable CCC to make such a recommendation in say January 2011, sufficient new modelling would need to have been conducted by the end of 2010. The % reduction figure could be published and subsequently applied to real CRC data to estimate an actual absolute cap. This can initially be done when the first year of CRC data is available (summer 2011) but the figure should not be published as it may still be erroneous. In summer 2012 when the second set of actual data is available the caps and relative reductions can be recalculated and the caps adjusted. At this point an absolute cap could be published.

12.4.2. Flexibility of annual cap setting

The capped phases of the CRC are each five years in length. It would be possible to announce firm caps for each year in a five year phase but this would give very little flexibility to make adjustments for influencing factors such as economic circumstances (e.g. another recession) or poor modelling of technology uptake rates.

The most flexible approach would be to set each annual cap only one or two years in advance taking into account all such influencing factors. However, that leaves participants with a great deal of uncertainty regarding future cap levels which makes investment planning more difficult.

The ideal compromise would be a set of pre-published cap estimates that are regularly reviewed and updated to take account of all these uncertainties.

12.4.3. Allocation problems: making the CRC robust and flexible

It is important to learn lessons from the EU ETS and UK ETS experience – these emissions trading systems have over allocated emissions resulting in a crashing carbon price and high emissions. In conjunction with this experience is the fact that models of abatement potential will never be perfect. Expert opinion[63] suggests that abatement potential in such models is often over estimated in the short term for example because hidden costs may not be adequately factored in. In the long term the abatement potential is considered to be pessimistic. This is because the models do not include the impacts on savings potential gained through the interactions of measures, policies and leverage effects of both. Innovation may also not be accurately portrayed. Over-allocation of allowances (i.e. through a too generous cap) is still therefore a possibility for the CRC. Domestic action on energy efficiency and carbon savings through the setting of the CRC cap must underpin the carbon price in the short term. The CCC should include in its cap guidance to Government recommendations for how best to avoid/deal with potential over-allocation should it become an issue, say in a couple of years into the capped phase.

- The way the cap is set needs to be sufficiently flexible to allow Government to response to events around uncertainty.
- The safety valve mechanism for buy-out must interact flexibly with the cap to allow Government response to events e.g. to allow safety valve price minimum to be changed within a capped phase. It may not necessarily be appropriate for the marginal burden to be less for CRC participants in comparison to the EU ETS.

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[63] CCC and project delivery team 18 May 2010

- It might be useful to establish set numbers of allowances available through the auction at certain prices i.e. auction reserve price.

12.4.4. Savings in Traded and Non-Traded sectors

As outlined in section 10 we have estimated that around 70% of CO_2 emissions from CRC participants come from electricity usage and only 30% from fossil fuel usage. The electricity used comes from the "traded sector" as UK power stations are part of the EU ETS. The fossil fuel usage of CRC participants comes from the "non-traded sector" as it is not in the EU ETS[64].

In 2017 the modelled abatement potential for energy efficiency measures is 16.1 $MtCO_2$. Taking into account the split described above this implies that savings of 11.3 $MtCO_2$ will be from the traded sector and 4.8 $MtCO_2$ from the non-traded sector.

This does not negate the importance of the role that non-domestics and domestic sectors can make to reduce their electricity use through demand side measures, and the need for policies to achieve this (e.g. CRC, CERT and products policy). The issue is how the EU ETS target or cap takes into account savings to electricity use made through other policies e.g. the CRC. The cap calculation for Phase 3 of the EU ETS does not take into account any impacts of the CRC, and only acknowledges that the costs of making savings might be in a different sector to where the actual carbon reductions are made. The savings made in the traded sector will contribute towards the targets in the EU ETS. CCC may wish to consider whether this "undermines" the effectiveness of EU ETS targets.

[64] Note, any fossil fuel used by a CRC organisation is specifically excluded from the CRC and has already been removed from the baseline estimates

13. References

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DECC, unpublished (December 2009) Note explaining different carbon savings from CRC, unpublished

DECC (October 2009) multiple documents listed below all of which are available from: http://www.decc.gov.uk/en/content/cms/consultations/crc/crc.aspx

Final Impact Assessment on the Order to Implement the Carbon Reduction Commitment Energy Efficiency Scheme

Government Response and Policy Decisions

Addendum to the Government Response to the Consultation on the Draft Order to Implement the CRC Energy Efficiency Scheme

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Appendix A ENUSIM and N-DEEM

ENUSIM Updates

Previous updates mean that sectors responsible for almost 90% of industrial emissions would have been updated since 2005. These updates were mainly aimed at sectors affected by the EU ETS and CCAs – which are sectors that are excluded from the CRC. The 2008 update did not uncover significant new evidence to adjust the data in ENUSIM. The existing data represented the most robust evidence available for these sectors. Other ENUSIM updates include the following.

1) In 2008: updating chemicals, manufacturing of cars and motors, food and drink. In the time available it was only possible to update manufacturing of cars and motors sector.
2) In 2005: to the EU ETS sector, including abatement potential and some market data.
3) In 2001-02: updating abatement potential and some market data for other sectors.

ENUSIM Scenarios

In the ENUSIM model, BAU refers to a scenario in which it is assumed that current policies continue. It is based on current energy consumption in a base year (different base years for different industry sector), which is extrapolated over time based on GDP growth rates and on the business as usual uptake of technologies. Hence, without specifying particular policies, BAU assumes policies in place in the base year continue or are replaced with new policies which have a similar impact on uptake rates. Note this is not the same as BAU in this modelling which is effectively the baseline.

Table 23 ENUSIM scenarios

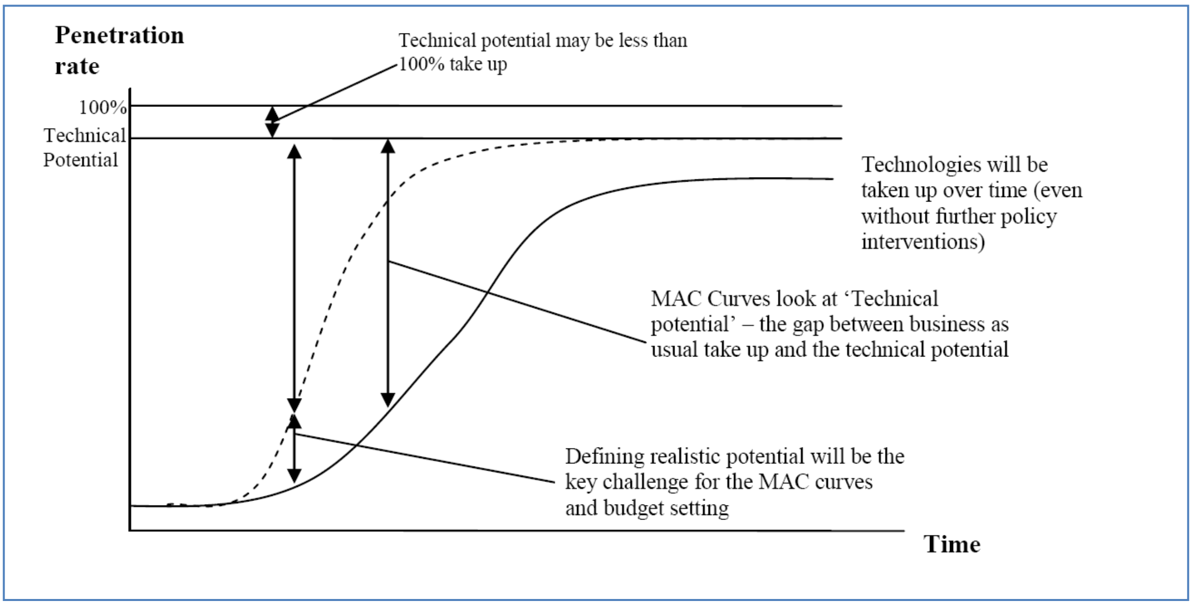
Scenario	Assumes that...
Business-as-usual (BAU)	technologies will continue to be taken up at current rates, and that the final saturation point is determined by behavioural preferences in the market, not necessarily determined by the cost-effectiveness of the technology option
All-cost-effective (ACE)	technologies are taken up wherever it is cost-effective to do so, and that the barriers or constraints on uptake are reduced relative to business as usual
All-technically-possible (ATP)	the technology is applied wherever it is cost effective to do so and there are no constraints to that uptake

Source: SKM Enviros, Ecofys, Entec UK (2010)

How ENUSIM Works

The below figure illustrates how ENUSIM works, this should be read in conjunction with 5.2.4.

- **Figure 6 Uptake of measures over time in a MACC**



Source: chart taken from AEA for CCC 2008, figure 2.1

Further Description of N-DEEM

The model incorporates a series of 'exemplar' buildings that represent each of the building types identified within N-DEEM. The model is defined in terms of floor areas and external surface areas for opaque fabric and glazing and their use is defined in terms of internal heat gains for lighting, people and equipment. The model is calibrated such that the overall energy consumption is broadly in line with the empirical information from the Energy Efficiency Best Practice Guides developed in the 1990s (BRE).

N-DEEM Updates

- 2004: updates included costs estimates, penetration rates, emissions factors and the addition of some technologies; updates were based on various studies and discussions with industry experts;
- 2007-08: updates included data on penetration rates, fuel prices, carbon emission factors and renewable energy technologies. The update was technology-specific and then it was scaled up to a sector level.

Appendix B Carbon savings estimates

Table 24 Carbon savings estimates by study

Study	Annual cost effective carbon savings estimate (MtCO2)	Parameter values driving estimate of carbon savings	CRC features (threshold (MWh) & start date)	Comments (e.g. modelling used, alternative scenarios run, overlap of savings)
(5) Enviros/ NERA 2006	By 2015, 2.2 By 2020, 4.8	Carbon price (£/ tCO2): 16 Discount rate default: 10% Grid factor (tCO2/ MWh): 0.43 High fuel prices scenario: 5.2 p/kWh for electricity, 1.3 p/kWh for gas Low price scenario: 3.4 p/kWh for electricity,1 p/kWh for gas	3,000 MWh 2008	Other threshold (MWh) scenarios run: 0; 2,000; 10,000. Alternative discount rate: 3.5% Abatement potential based on ENUSIM and N-DEEM.
(8) *CCC Review and update 2008	In 2012, 4.03 In 2017, 3.47 In 2022, 3.46	Discount rate default: **3.5%** Grid factor (tCO2/ MWh): **0.38** Energy White Paper 2007, central set of prices: for electricity **10.46**p/kWh, for gas **2.58**p/kWh	3,000 MWh	Abatement potential based on **updated versions of ENUSIM and N-DEEM off-models**.
(14) EA 2009	By 2020, **9.2	Carbon price (£/ tCO2): **0** Discount rate: 3.5% Grid factor (tCO2/ MWh): **0.43** Pre-recessional UEP 32 (**lower fuel prices** than in Energy White Paper 2007), central scenario	**6,000 MWh** 2010	Abatement potential determined from **updated off-models** originally used for the CCC 2008 analysis (updates of ENUSIM and N-DEEM)

Notes:

(5) Enviros/ NERA 2006: total cost effective potential is given as 9.5 MtCO2 if taken from p4 at £0/ tCO2, at £16/ tCO2 total potential is given as 12.1 MtCO2.

(8) *CCC 2008: this study was not designed to model carbon savings specifically for the CRC. The annual cost effective carbon savings estimates provided are compiled from estimates of estimated delivery from the manufacturing sector (2012, 0.63 MtCO2; 2017, 0.47MtCO2; 2022, 0.46 MtCO2) and from the commercial and public sectors (2012, 3.4; 2017, 3; 2022, 3).

(14) EA 2009 **9.2 MtCO2 annual cost effective carbon savings estimate is the lower estimate, cost effective at £0/tCO2 (p33): upper estimate of 13.82 MtCO2 and best estimate of 11.6 MtCO2. The total abatement potential of 16 MtCO2 is the potential available with a high carbon price.

Table 25 Carbon savings estimates and assumptions from DEFRA CRC consultations/ Impact Assessments

Study	Annual cost effective carbon savings estimate (MtCO2)	Parameter values driving estimate of carbon savings	CRC features (threshold (MWh) & start date)	Comments (e.g. modelling used, overlap of savings)
(6) DEFRA First consultation 2006	By 2015, 1.8 In 2020, **4.4**	Discount rate: 10% Carbon price: £16/ tCO2 High fuel price scenario: 5.2 p/kWh for electricity and 1.3 p/kWh for gas Low price scenario: 3.4 p/kWh for electricity and 1 p/kWh for gas	3,000 MWh **2009**	Uses abatement potential modelling from (5) above. Revised carbon savings estimate (from (5)) due to 2009 start year.
(7) DEFRA IA consulting on options 2007	By 2015, 1.8 In 2020, **4.0**	Discount rates: 3.5%, 10% Fuel prices as for (6) above	**6,000 MWh** 2009	Uses abatement potential modelling from (5) above. Includes 0.4 MtCO2 overlap with smart meters and EPBD. Excludes 0.4 MtCO2 delivered through another element of EPBD.
(9) DEFRA Partial IA 2009	In 2020, **3.6**	**Fuel prices** not available but DECC note states these were **higher** than in previous IAs (i.e. 6 &7)	6,000 MWh **2010**	Uses abatement potential modelling from (5) above. Includes 0.4 MtCO2 overlaps with smart meters and EPBD claimed by CRC. Excludes 0.4 MtCO2 delivered through another element of EPBD. **Includes 0.4 MtCO2** from EUA purchase.
(13) DECC Final IA 2009	In 2015, 1.3 In 2020, **3.2**	Discount rates: 3.5%, 10% Carbon price (£/tCO2): 16 Grid factor(tCO2/ MWh): 0.43 High fuel price scenario: **10.1** p/kWh for electricity, **2.6** p/kWh for gas Low price scenario: **6.8** p/kWh for electricity,**1.7** p/kWh for gas	6,000 MWh 2010	Uses abatement potential modelling from (5) above. Includes 0.4 MtCO2 overlaps with smart meters and EPBD claimed by CRC. Excludes 0.4 MtCO2 delivered through another element of EPBD. **Excludes 0.4 MtCO2** from EUA purchase.

Notes: **bold** text indicates where a **change** can be seen **in comparison to the previous study** in the list (**or in comparison to another** specified study) in the carbon savings estimates or features of the modelling from which the savings estimates are produced. Energy prices for (6) and (7) are assumed to be the case based on reading of reports, clarification by DECC not possible. Source: SKM Enviros, Ecofys, Entec UK (2010)

Appendix C Renewable heat studies

- **Table 26 Renewable heat studies outlined**

Study	Sectors/ sub-sectors covered	Outputs	Source data
CCC Heat model and report 2009	Commercial, domestic, public and industrial England, Wales, Scotland and Northern Ireland	Marginal cost of abatement under maximum technological potential and under a 'realistic' scenario Most abatement potential below £100/tCO2 is within industry	BERR End Use Sector, AEA, modelling by NERA (2009)
DECC RH supply curve 2009	Commercial, domestic, industrial, public – not disaggregated further	Marginal costs of achieving 8.5% and 12% of UK heat use from renewable heat by 2020 (3 scenarios) For higher growth scenario: carbon abatement potential for EU ETS installation – 6.9 MtCO2, non-EU ETS 6.1 MtCO2 For central growth scenario: carbon abatement potential for EU ETS installations – 6.8 MtCO2, for non-EU ETS 6.7 MtCO2	English Housing Condition Survey, BRE Domestic Energy Factfile, ENUSIM, N-DEEM, CT, AEA

Source: SKM Enviros, Ecofys, Entec UK (2010)

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Appendix D Revised sectors and coverage

Table 27 CRC sectors and coverage estimates (for the high scenarios)

High Level Group	Sector	Total Sector Emissions ($MtCO_2$)	% Exclusion for CCA / EU ETS	% Exclusion for 25% CCA rule	Potential CRC Emissions ($MtCO_2$)	% under CRC threshold		CRC Emissions Estimate ($MtCO_2$)	
						6,000 MWh	3,000 MWh	6,000 MWh	3,000 MWh
Private-industrial	Iron & steel	23.4	89	7	0.94	20	15	0.75	0.80
	Non-Ferrous metals	5.4	88	7	0.27	20	15	0.21	0.23
	Mineral products	9.5	88	5	0.67	20	15	0.53	0.57
	Chemicals	19.6	85	10	0.98	50	45	0.49	0.54
	Mechanical engineering & metal products	6.2	20	5	4.66	50	45	2.33	2.56
	Electrical & instrument engineering	4.7	10	5	3.96	50	45	1.98	2.18
	Vehicle Manufacture	5.1	20	15	3.32	30	25	2.32	2.49
	Food & beverages	12.4	85	10	0.62	30	25	0.43	0.46
	Textiles & leather	3.4	40	15	1.51	30	25	1.06	1.13
	Paper, printing	9.7	85	10	0.49	20	25	0.39	0.36
	Construction	1.8	0	0	1.78	60	50	0.71	0.89
	Rubber and plastics	10.0	25	10	6.50	50	45	3.25	3.58
	Water	3.5	0	0	3.50	0	0	3.50	3.50
	Other	10.3	15	5	8.20	60	50	3.28	4.10
	Energy supply	44.0	98	0	0.88	0	0	0.88	0.88
	Agriculture	3.9	30	10	2.31	65	55	0.81	1.04
	Industrial Sector total	**172.7**			**40.58**			**22.93**	**25.31**
Private - non-industrial	Retail: supermarkets	11.5	0	0	11.50	0	0	11.50	11.50
	Retail: department stores/ malls	4.5	0	0	4.50	20	15	3.60	3.83
	Retail: small shops	7.5	0	0	7.50	75	65	1.88	2.63
	Warehouses & Wholesale	3.5	0	0	6.70	60	55	2.68	3.02
	Hospitality: hotels	6.7	0	0	6.70	60	55	2.68	3.02
	Hospitality: restaurants	6.7	0	0	10.06	50	40	5.03	6.04
	Offices	10.1	0	0	4.47	50	40	2.24	2.68
	IT & Internet	4.5	20	10	2.45	40	35	1.47	1.59
	Laundries	2.0	25	10	1.30	40	35	0.78	0.85
	Other (inc. Media, Sport)	2.0	0	0	2.00	40	35	1.20	1.30
	Commercial Sector total	**58.9**			57.19			**33.05**	**36.44**
Public	Central Government (includes MOD)	4.5	1%	0	4.46	0	0	4.46	4.46
	Local Government (inc. LA schools)	12.5	1%	0	12.38	30	25	8.66	9.28
	Health	5.0	15%	0	4.25	40	35	2.55	2.76
	Education (exc. LA schools)	3.4	10%	0	3.06	40	35	1.84	1.99
	Public Sector total	**25.4**			24.14			**17.50**	**18.49**
	CRC sector total							**73.5**	**80.2**

Appendix E DECC Energy projections: Central scenario growth rates

- **Table 28 DECC Energy projections: Central scenario growth rates, by year and subsector**

Subsector	Growth rate													
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mechanical Engineering	-7.6%	-4.1%	-1.4%	0.1%	0.8%	1.0%	0.7%	0.6%	0.6%	0.6%	0.7%	0.7%	0.7%	0.7%
Electrical Engineering	-7.6%	-4.1%	-1.4%	0.1%	0.8%	1.0%	0.7%	0.6%	0.6%	0.6%	0.7%	0.7%	0.7%	0.7%
Vehicle Manufacture	-7.6%	-4.1%	-1.4%	0.1%	0.8%	1.0%	0.7%	0.6%	0.6%	0.6%	0.7%	0.7%	0.7%	0.7%
Rubber and plastics	-7.6%	-4.1%	-1.4%	0.1%	0.8%	1.0%	0.7%	0.6%	0.6%	0.6%	0.7%	0.7%	0.7%	0.7%
Water	-7.6%	-4.1%	-1.4%	0.1%	0.8%	1.0%	0.7%	0.6%	0.6%	0.6%	0.7%	0.7%	0.7%	0.7%
Construction and other	-7.6%	-4.1%	-1.4%	0.1%	0.8%	1.0%	0.7%	0.6%	0.6%	0.6%	0.7%	0.7%	0.7%	0.7%
CCA residual industry	-7.6%	-4.1%	-1.4%	0.1%	0.8%	1.0%	0.7%	0.6%	0.6%	0.6%	0.7%	0.7%	0.7%	0.7%
Supermarkets	3.1%	1.7%	1.2%	1.5%	1.5%	1.5%	1.3%	1.1%	1.0%	0.8%	0.7%	0.7%	0.8%	0.8%
Dept Stores	3.1%	1.7%	1.2%	1.5%	1.5%	1.5%	1.3%	1.1%	1.0%	0.8%	0.7%	0.7%	0.8%	0.8%
Small Shops	3.1%	1.7%	1.2%	1.5%	1.5%	1.5%	1.3%	1.1%	1.0%	0.8%	0.7%	0.7%	0.8%	0.8%
Hotels	3.1%	1.7%	1.2%	1.5%	1.5%	1.5%	1.3%	1.1%	1.0%	0.8%	0.7%	0.7%	0.8%	0.8%
Restaurants	3.1%	1.7%	1.2%	1.5%	1.5%	1.5%	1.3%	1.1%	1.0%	0.8%	0.7%	0.7%	0.8%	0.8%
Offices	3.1%	1.7%	1.2%	1.5%	1.5%	1.5%	1.3%	1.1%	1.0%	0.8%	0.7%	0.7%	0.8%	0.8%
IT and Internet	3.1%	1.7%	1.2%	1.5%	1.5%	1.5%	1.3%	1.1%	1.0%	0.8%	0.7%	0.7%	0.8%	0.8%
Warehouses and wholesale	3.1%	1.7%	1.2%	1.5%	1.5%	1.5%	1.3%	1.1%	1.0%	0.8%	0.7%	0.7%	0.8%	0.8%
Other (inc. Media, Sport)	-2.1%	-2.2%	-0.5%	-0.1%	0.1%	0.2%	0.2%	0.1%	0.1%	0.0%	-0.1%	-0.2%	-0.4%	-0.3%
Central Government	-2.1%	-2.2%	-0.5%	-0.1%	0.1%	0.2%	0.2%	0.1%	0.1%	0.0%	-0.1%	-0.2%	-0.4%	-0.3%
Local Government	-2.1%	-2.2%	-0.5%	-0.1%	0.1%	0.2%	0.2%	0.1%	0.1%	0.0%	-0.1%	-0.2%	-0.4%	-0.3%
Health	-2.1%	-2.2%	-0.5%	-0.1%	0.1%	0.2%	0.2%	0.1%	0.1%	0.0%	-0.1%	-0.2%	-0.4%	-0.3%
Education	-2.1%	-2.2%	-0.5%	-0.1%	0.1%	0.2%	0.2%	0.1%	0.1%	0.0%	-0.1%	-0.2%	-0.4%	-0.3%

Source: DECC energy model (UEP). Table: Final Energy Consumption In Commercial and Public sector. Available from: http://www.decc.gov.uk/en/content/cms/statistics/projections/projections.aspx

Appendix F Fuel price projections

Table 29 Fuel prices assumed in the modelling of the Central scenario

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
electricity_commercial	7.9	8	8.1	8.1	8.1	8.2	8.3	8.3	8.4	8.5	8.5
fossil fuel_commercial	6.17	6.26	6.34	6.4	6.48	6.57	6.65	6.71	6.8	6.88	6.97
electricity_industrial	6.9	7	7.1	7.1	7.1	7.2	7.3	7.3	7.4	7.4	7.5
fossil fuel_industrial	6.27	6.36	6.45	6.52	6.61	6.71	6.8	6.86	6.96	7.05	7.15

Source: DECC Fuel Price Projections; Tables 4-9. Fossil fuel values were derived based on a weighted average of gas (87.2%) and oil (12.8%) multiplied by DECC's Variable price for commercial and industrial sectors.

Appendix G Renewable electricity assumptions

The following summary is taken directly from BRE's technical documentation submitted to the CCC (2009).

Photovoltaics (PV)

The total potential for electricity generated by PV in the UK commercial sector was obtained from a report produced by the University of Northumbria Hill, Pearsall and Claiden, The Potential Generating Capacity of PV-Clad Buildings in the UK: Volume 1, Newcastle Photovoltaics Applications Centre, University of Northumbria, 1992.

The total capacity provided in the report includes instances where PV may provide an over-generation of power in the summer months and therefore be available to feed into the grid; since we are only interested in the useful power supplied to the building, this was taken into account by using monthly demand and generation data for a sample building[65] to estimate that around 20% of the generated power may be fed into the grid. It was assumed that approximately 30% of the total potential was for roofs and the remaining 70% was for walls, based on a breakdown of annual solar input per unit surface area for walls and roofs taken in sample in Plymouth. Where PV could be fitted to walls as an alternative to cladding, a marginal cost was used. For roofs, it is possible to replace standard roof tiles with PV tiles; however, more detailed analysis indicated that this was the least cost effective option for roof PV systems. Since the energy audit data cannot provide information on the angle of the roof, the direction in which it faces and the shading from other buildings and trees it was not possible to break down the analysis into the cost effective and non-cost effective potentials. As it is widely acknowledged that at current prices PV is not cost effective, this does not present a major issue. A figure of 732 kWh/kWp [i].was determined from DUKES figures for total installed PV capacity and total power generation from PV to indicate the expected power supplied from the potential to be installed.

61 Hill, Pearsall and Claiden, The Potential Generating Capacity of PV-Clad Buildings in the UK: Volume 1, Newcastle Photovoltaics Applications Centre, University of Northumbria, 1992.
i kWpeak is the power generated under optimum conditions, the kWh/kWp figure provides an indication of the actual power likely to be generated in UK conditions
j DTI, Digest of UK Energy Statistics, HMSO, 2004.

Appendix H Energy efficiency barriers and incentives

Table 30 Summary of barriers to uptake of energy efficiency measures

Energy efficiency measure	Summary of barrier
Monitoring and targeting	The majority of organisations in every sector tended to have no sub metering and no monitoring and targeting programme. This was because of (1) lack of awareness of the benefits (2) lack of time and ownership to make the case and assess the results.
Behaviour change	In the absence of monitoring and targeting it is difficult to demonstrate the impact of behaviour change and to keep up the momentum of initiatives. Staff turnover and language (28 languages spoken at one food packing site) is also a barrier to altering behaviour in manufacturing. In the public sector, the wide target audience from patients through to visitors and office staff mean engagement would need to operate at all levels to succeed.
Insulation	Loft and wall insulation is only perceived as a major opportunity at refurbishment stage as it is difficult to retrofit without major disruption. Pipe insulation is often overlooked and is far less disruptive.
Lighting e.g. new efficient light sources, controls	Lighting is a fast moving technology with developments in LEDs, controls, timers, use of daylight and bigger windows. There are many cost effective options but well written and carefully targeted guidance would be helpful to encourage faster uptake e.g. lighting in leisure centres or shops. Barriers to lighting controls and sensors in the NHS include safety, security and trust.
Space heating e.g. building energy management, boiler efficiency measures	Space heating control improvements and boiler efficiency measures were seen as having the most carbon saving potential in every sector. Although improvements to space heating management are often overlooked due to lack of maintenance and knowledge, there are very few barriers to prevent action.

Energy efficiency measure	Summary of barrier
Boilers e.g. replace steam boilers with CHP, renewable heat	Reluctance to commit capital hinders the installation of new boilers in all sectors and the tendency is to wait for boiler failure. CHP's major barrier is spark price variability (if the ratio of electricity price to gas price drops then pay back time is affected): it is difficult to convince organisations what the future electricity price would be. Low uptake in the private sector.
Motors, pumps and compressed air	Lack of awareness of VSDs and controls means that they are often over looked. There is some potential for motors/VSDs on air handling units in all sectors. Procurement of motors should be easy to change – basic policy, particularly in the NHS, is still just to go for cheapest motor and overlook whole life cost. The public sector is very keen on voltage optimisation, particularly at leisure centres, but the real impacts need measuring to demonstrate if true energy savings are made.
Waste heat recovery	Payback period for waste heat recovery for new buildings is low but retrofit costs higher. Ventilation systems bringing in fresh air to buildings are an often overlooked opportunity for waste heat recovery, due to a lack of skills in that area.
Maintenance	Maintenance job definition is "no complaints" but boilers may well not be running efficiently. Maintenance is still not targeted at building performance.
Refrigeration and air conditioning	Lack of understanding of opportunities, lack of people to deliver in terms of equipment and maintenance. Lack of metering to indicate problems.
Ventilation	Lack of control of system, fixed speed, on all the time, need ventilation on demand control system. Examples include: toilet ventilation as needed, a passive IR lighting system linked in and CO2 sensors in office for ventilation fans. People need to understand potential to apply control.
Domestic hot water	Not such a big issue and few barriers - most very old pipework has now been replaced.

Source: SKM Enviros, Ecofys, Entec UK (2010)

Table 31 General barriers to uptake of energy efficiency measures

	Financial resources	Time resources	Payback time	Lack of awareness of technology	Lack of confidence in technology	Lack of supply of technology	Conflicting priorities	Lack of trained engineers	Difficult to retrofit	Planning issues (renewables)	Hassle	Political issues	Behaviour change
Private sector offices and hotels	XX	XX											
Light industry outside EU ETS and CCAs	XX	XX	XX	X	X	X	XX	X	X	X			
Food supply chain (light manufacturing etc)	XX		XX				XX	X	X		X		
NHS	XX		XX				X	X	XX		XX	X	
Local authorities	XX	XX		X					X		XX	X	X

Note: XX=large barrier, X=smaller barrier. Source: SKM Enviros, Ecofys, Entec UK (2010)

▪ Table 32 Detailed summary of energy efficiency incentives discussed during industry expert interviews

Sector(s) suggested for	Incentive	Pros and cons	Impacts e.g. high/med/low & speed uptake or other
Loans			
Local Authorities Food supply chain	Simplified loan application process	Pros: A simplified loan scheme application process should see faster uptake. At present getting SALIX and Carbon Trust funding takes a significant amount of time and effort.	Speed uptake Med/low long term impact
		Pros: better support / simplification would certainly make a difference	
		Cons: Simpler process means less information and control of process	
Carbon management support			
NHS	NHS carbon management programme from CT could be expanded to increase impact	Pros: Not enough carbon management tools available for NHS yet, this could fill gap. Aim for CM as part of culture of organisation.	Medium
		Cons: requires more funding and more dependence on outside help (not internal staff)	Will have some impact on speeding uptake
Private sector offices and hotels	Ring fence some of CRC revenue recycling for energy management and advice.	Pros: Instead of recycling revenue directly, targeted specifically with advice and energy management support would ensure revenue was not lost on general business overheads.	High
		Pros: Companies need more than just an audit – they need ongoing support and linking to services.	
		Cons: resistance from the private sector and larger companies, reduces flexibility.	

Sector(s) suggested for	Incentive	Pros and cons	Impacts e.g. high/med/low & speed uptake or other
Training			
Light industry outside EU ETS and CCAs	Training package providing training for consultants, maintenance engineers, equipment suppliers.	Pros: help to break down barriers of shortage of trained engineers, complex retrofit and confidence/awareness in technology.	Medium
Information and guidance			
NHS	Guidance on how individuals in NHS can reduce carbon. E.g. nurse roles. Bringing EE behaviour at home to work. Shutting blinds and curtains on hot days. Very little material available.	Pros: A key step to getting grass roots behaviour change in NHS and to building trust on energy saving not compromising patient heal Enthusiasm for action – good corporate citizen and leader in community, but do not have the tools to do it day to day.	Behaviour change can affect1% to 5% of energy use, more information will help this, so low to med impact.
Food supply chain (light manufacturing etc)	Knowledge transfer through supply chain workshops / online networks	Pros: working better together in the supply chain to ensure the cascade of energy efficient bespoke technologies gets maximum roll out. Learn from Carbon Trust Accelerator Programme. Cons: reluctance to share information when competing against each other on CRC league table	Low/med

Sector(s) suggested for	Incentive	Pros and cons	Impacts e.g. high/med/low & speed uptake or other
Local Authorities Light industry outside EU ETS and CCAs	Technology information and guidance to apply to voltage optimisation, lighting, BEMs, use of VSDs on pumps and fans and refrig and air con.	Pros: Commitment across all sectors. Pros: Gap in knowledge concerning results from installing voltage optimisers at sites such as leisure centres. Research to demonstrate cause and effect would be useful to speed uptake (need half hourly monitoring).	High Speed uptake
Monitoring and targeting			
Private sector offices and hotels Light industry outside EU ETS and CCAs	Provide support & advice to help purchase M&T system and drive initial behaviour change – Carbon Management on a condensed format. Increase CT funding and reduce revenue recycled.	Pros: massive gap to fill on sub metering, monitoring and targeting for private sector sites. Linking M&T with behaviour change and measuring impact of campaigns will help maintain motivation. Addresses barriers to lack of understanding of benefits of M&T in fast moving field.	High

Source: SKM Enviros, Ecofys, Entec UK (2010)

Table 33 Summary of incentives suggested

Grouping	Incentive suggested in interview	Sectors affected	Pros	Cons	Estimated Impact	Speed uptake
Loans	EE Loans (simplified application process)	Private sector (smaller organisations) and public sector	X	X	Med	Yes
Carbon management	Ring fence CRC revenue for intensive carbon management support	CRC population	X	X	High	Yes
Training	Training for consultants, maintenance engineers & equipment suppliers	CRC population & suppliers	X		Med	-
Info & guidance	Behaviour change guidance	NHS	X		Low	No
Info & guidance	Enhance supply chain knowledge transfer (workshops & web)	Lighter industry	X	X	Low	Yes
Info & guidance	Tailored information & guidance on EE technologies	CRC population	X		High	Yes
M&T	Monitoring & targeting funding and advice	CRC population	X	X	High	Yes
Contractual	Tighter outsourcing contracts on EE responsibilities and CRC exposure clarity	Public sector buildings managed by contractors	X		Med	-
Financial	Grants for EE technology	CRC population	X	X	High	Yes
Financial	Secure benefits e.g. For non renewable CHP	Light manufacturing / public sector (with high heat load)	X	X	High	Yes
Financial	Reducing payback time under three years	CRC population	X	X	High	Yes
Financial	Cost of carbon secure	CRC population	X	X	High	Yes

Note: In the 'speeds uptake' column, 'yes' means the measure would speed up uptake of energy saving measures, 'no' means it would not. Source: SKM Enviros, Ecofys, Entec UK (2010)