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Feasibility study on improving the evidence base for industrial energy efficiency

Phase 1 Report – Rapid evidence base assessment – 12th November 2013

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Executive Summary

This interim report has been commissioned by the Department of Energy and Climate Change (DECC). The project comprises of two phases. Phase 1 provides a survey of all significant evidence that contributes to answering three key questions: what are the existing trends in industrial process energy use; what is the technical and economic energy efficiency potential over the coming decades; and what are the barriers to uptake of energy efficiency improvements, including the question of what evidence exists that quantifies or compares barriers. Phase 2 provides a report that identifies any gaps in the overall coverage and indicates where there are opportunities for making cost-effective improvements to the evidence base. This interim report presents the Phase 1 findings.

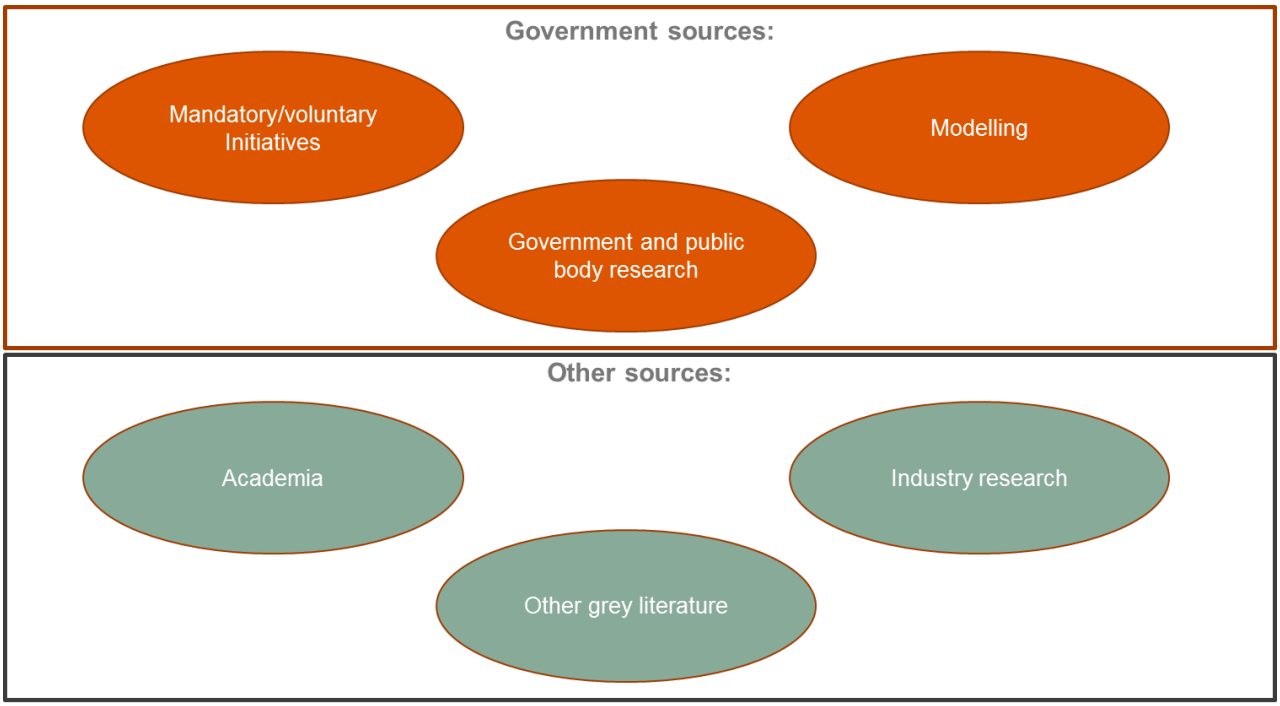
Background

Improving the evidence base for industrial energy efficiency is a key deliverable for the Energy Efficiency Strategy published on 12 November 2012. At the EEDO Strategy launch event at the Royal Society on 4 February 2013 the Prime Minister said: *"The economies that will prosper, are those that are the greenest and the most energy efficient"* and *"making energy consumption more efficient is a vital part of the growth and wealth that we need"*.

The overall purpose of the research is to provide a basis on which Government can best target cost-effective measures to improve the evidence base on industrial energy efficiency. This feasibility study therefore includes setting out a comprehensive overview of existing research evidence relating to answering key questions on energy use trends, energy efficiency potential and barriers.

Approach

A rapid evidence assessment of the industrial energy efficiency evidence base was implemented in the Phase 1study. Data was gathered from six sources:



Findings

Overall the evidence base is patchy. There is significant variation in the quality and coverage of data between sectors.

Energy trends are well understood in regulated large consuming sectors, but poorly understood in unregulated small consuming sectors. The study estimates that 15% of industrial energy consumption is currently not in a form to allow for deep analysis of sector energy trends. This is primarily the result of these sectors not being covered by either Climate Change Agreements (CCAs) or the EU Emissions Trading Scheme (EU ETS).

Abatement potential data is at best moderate. There is limited primary data available for many of the key parameters. There are also great difficulties in comparing datasets and studies meaning that adopting a patchwork approach to gap filling is hindered.

Data on barriers is often restricted to qualitative appraisals. However, international studies provide useful precedents on how to improve evidence, often relying on data gathered through wider energy efficiency programmes.

There are a number of emerging initiatives and academic programme which could offer significant improvements in data over next 2 – 3 years. This includes UKERC Energy Demand project, which is being led by a number of the leading academic institutions in the UK and government funded research, such as the carbon road maps.

There may also be scope for new useful data to be derived from existing schemes, such as CCAs and Enhanced Capital Allowances (ECAs). CCAs could provide additional information on site energy performance in a sector, whilst ECAs could provide information on technology uptake rates.

1. Introduction

This interim report has been commissioned by the Department of Energy and Climate Change (DECC). The project comprises of two phases. Phase 1 provides a survey of all significant evidence that contributes to answering three key questions: what are the existing trends in industrial process energy use; what is the technical and economic energy efficiency potential over the coming decades; and what are the barriers to uptake of energy efficiency improvements, including the question of what evidence exists that quantifies or compares barriers. Phase 2 provides a report that identifies any gaps in the overall coverage and indicates where there are opportunities for making cost-effective improvements to the evidence base. This interim report presents the Phase 1 findings.

1.1 Background

Improving the evidence base for industrial energy efficiency is a key deliverable for the Energy Efficiency Strategy published on 12 November 2012. At the EEDO Strategy launch event at the Royal Society on 4 February 2013 the Prime Minister said: *"The economies that will prosper, are those that are the greenest and the most energy efficient"* and *"making energy consumption more efficient is a vital part of the growth and wealth that we need".* Analysis suggests energy savings of 20-63TWh in 2020 and 28-68TWh in 2025 may be possible from industrial energy efficiency. This includes processes across all industrial sectors, and use of electricity, gas and other fuels within processes.

To deliver this, the Energy Efficiency Strategy sets out a need for a stronger and more developed evidence base to underpin and guide the development of targeted, evidence-based policies which would help drive further energy efficiency improvements in a number of areas including the industrial sector. The current evidence points to potential particularly in the medium energy intensive sectors. However, the evidence which is currently used to assess the energy efficiency of industry and to calculate future potential has a number of shortcomings including reliability and extent of coverage. This limits the strength of the conclusions which can be drawn from it, and the extent to which it can provide a basis for design of new policy instruments.

1.2 Purpose

The overall purpose of the research is to provide a basis on which Government can best target cost-effective measures to improve the evidence base on industrial energy efficiency. This feasibility study therefore includes setting out a comprehensive overview of existing research evidence relating to answering key questions on energy use trends, energy efficiency potential and barriers. This also includes an assessment of the nature of the information available from each evidence source and a judgement on quality and reliability. By researching the evidence base in this way, will make it possible to highlight areas where improvements could most cost-effectively be made.

The study focused on three research questions:

- Research Question 1: What are the existing (and, where appropriate for context, historic) trends in industrial process energy use?
- Research Question 2: What is the technical and economic energy efficiency potential over the coming decades and resultant carbon emissions reductions?
- Research Question 3: What are the barriers to uptake of energy efficiency improvements?

2. Methodology

A rapid evidence assessment of the industrial energy efficiency evidence base was implemented in this study. The following sections outline the approach taken towards scope definition, quality parameters and also the lines of enquiry pursued in the study.

2.1 Scope

The study considered industrial energy efficiency within a number of themes: by sector, by technology and by barriers and enablers. To manage and organise the information gathered it was necessary to adopt a set of core definitions that would allow the analysis to be focused.

Sector activity was used as the basis for scoping. It is consistent with approaches taken in other industrial energy efficiency studies and the energy efficiency models used to assess such activities. As a result, the gathering, codifying and interpreting data is significantly simplified.

Standard Industrial Classifications were used to define the industrial activities within scope. These established definitions have been developed to define and group manufacturing processes for a range of reporting purposes. Furthermore, no alternative suitable typologies that covered all the activities within scope could be identified. The SIC codes assessed are set out in Table 1 below.

Table 1: SIC classifications for in scope activities

SIC Code and Description
C10 1 Processing and preserving of meat and production of meat products
C10 2 Processing and preserving of fish crustaceans and molluscs
C10 3 Processing and preserving of fruit and vegetables
C10 4 Manufacture of vegetable and animal oils and fats
C10 5 Manufacture of dairy products
C10 6 Manufacture of grain mill products starches and starch products
C10 7 Manufacture of bakery and farinaceous products
C10 8 Manufacture of other food products
C10 9 Manufacture of prepared animal feeds
C11 Manufacture of beverages
C12 Manufacture of tobacco products
C13 Manufacture of textiles
C14 Manufacture of wearing apparel
C15 Manufacture of leather and related products

SIC Code and Description
C16 Manufacture of wood and of products of wood and cork except furniture manufacture of articles of straw and plaiting materials
C17 Manufacture of paper and paper products
C18 Printing and reproduction of recorded media
C19 Manufacture of coke and refined petroleum products
C20 Manufacture of chemicals and chemical products
C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22 Manufacture of rubber and plastic products
C23 Manufacture of other non-metallic mineral products
C24 Manufacture of basic metals
C25 Manufacture of fabricated metal products except machinery and equipment
C26 Manufacture of computer electronic and optical products
C27 Manufacture of electrical equipment
C28 Manufacture of machinery and equipment n e c
C29 Manufacture of motor vehicles trailers and semi-trailers
C30 Manufacture of other transport equipment
C31 Manufacture of furniture
C32 Other manufacturing

In general, it was sufficient to collate data at 2 digit SIC code. This provides appropriate definition of industrial sectors to allow for meaningful distinctions in energy usage patterns. The only exception to this is the food and drinks sector, where due in part to sector heterogeneity and also the high availability of data and literature, a 3 digit SIC code was adopted.

2.2 Research workshop

At project inception a research workshop was held. Through this key tools and methods were developed and lines of enquiry in the evidence base were identified.

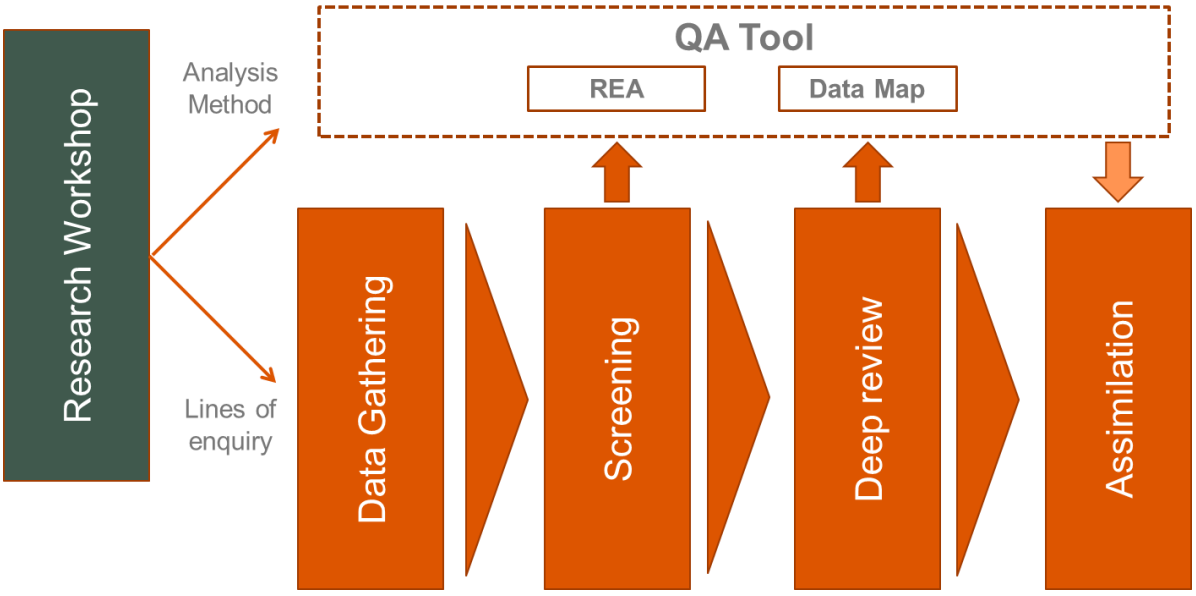


Figure 1: The role of the research workshop with respect to the wider programme

A Quality Assessment Tool (QA Tool) was used to record findings. This tool captured the evidence codification process form initial screening through to, if appropriate, more detailed analysis.

There are two components of the QA Tool;

- **Rapid evidence assessment:** This assesses the quality of the data source and its relevance to the research questions. Where sources are highly relevant they are subject to aggregate quality scores.
- **Data map:** Highly relevant datasets are subject to a deeper review. A range of parameters by research question and by sectors are coded and scored.

At the research workshop the scope of each aspect of the tool was defined. The quality definition used within the study was also determined. The workshop allowed the team to collectively discuss lines of enquiry. Datasets were identified, grouped and then routes to accessing the data were discussed.

2.3 Definition of quality

A standardised quality ranking method was used in the study. The quality scoring system is set out below (see Annex A, for enlarged version).

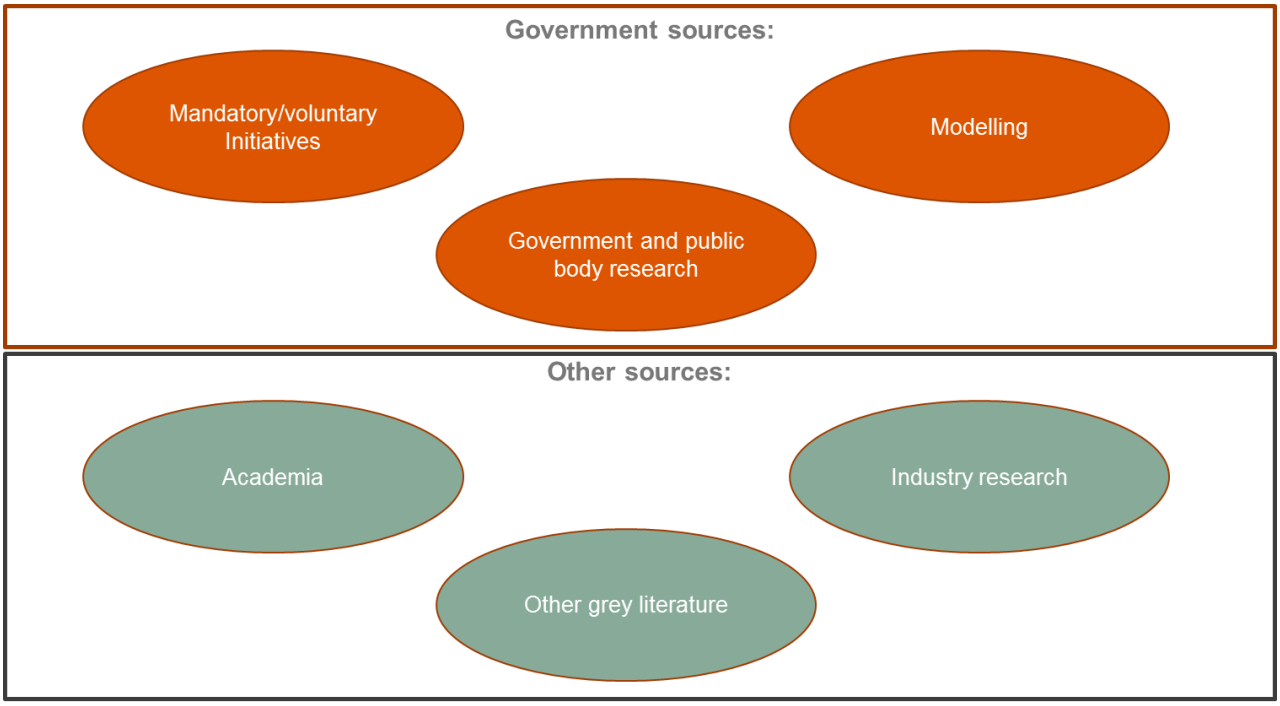
Code	Fit for our purpose (relevance)	Adapted Maryland rating	Research design quality		Quality of research delivery	Independence of study from delivery	Source of data
			Scale/robustness in terms of coverage	Representative?			
1	All aspects are relevant to our objectives	Quantified direct impacts (e.g. measures installed)	Total industry	Comprehensive representation of target group (Census)	Conducted in line with good practice (ISO20252 or similar) or subject to independent peer review	Independent study	Primary auditted data
2	Some aspects are relevant to our objectives	Quantified as part of an aggregate	Sample-based research/evaluation	Randomly selected sample, representative of the population (Limited or no bias)	Subject to internal peer review and commissioned by third party	Some aspects are independent	Primary data
3	Limited relevance to our objectives	Partially quantified	Case study approach	Sample selection is non-random and may not be representative of the population (either through non-random design or bias e.g. non-response bias)	Steps taken to ensure quality either not undertaken or not reported	Non-independent study	Primary and secondary data
4		Qualitatively appraised					Secondary data

The definition for each field is as follows:

- Fit for purpose – how appropriate and relevant is the data?
- Adapted Maryland rating – has the parameter in question been quantified?
- Scale – how substantial was the study sample population?
- Representativeness – how representative is the study to the target sectors in this study?
- Quality of research – what degree of quality assessment was applied to the study?
- Independence of study – is the study independent?
- Source of data – what is the source data type?

2.4 Lines of enquiry

The research workshop identified the following lines of enquiry:



2.4.1 Mandatory and voluntary schemes

For each of the mandatory and voluntary schemes all associated reports and forms were reviewed. For Climate Change Agreements, as an example, the tax returns (P10 forms), sector negotiation pro forms and the biennial formal sector reports were all assessed. The following schemes were assessed;

- EU ETS
  - NIMs Allocation pro formas
  - Annual submissions
- CCA
  - Tax returns
  - Sector submissions
  - Negotiations
  - Target performance reports
- ECA
  - Tax submissions
  - Evaluations
- CRC
  - Formal submissions
- ONS/DECC statistics
  - ECUK/DUKES
  - PRODCOM
  - IoP
- CHPQA
- CCL
- National inventory
- Pollution inventory
- DEFRA – Recycling statistics

2.4.2 Government studies

A number of public body studies were reviewed. This included publicly available studies from DECC, TSB, CCC and Carbon Trust. The review also accounted for further unpublished internal analysis.In total 46 papers were subject to a rapid evidence assessment. Of the 46 papers 31 were codified in the data map.

2.4.3 Models

When considering the models, the focus was on the underlying evidence used for parameters. The following models were subject to codification in the data map;

- MARKAL/TIMES
- ENUSIM
- NDEEM
- POLES
- NERA/ENVIROS model
- 2050 Pathway model

2.4.4 Academic literature

Academic papers were gathered through a journal search using search terms agreed with DECC.The journal search was supplemented through interview with a leading academic on industrial energy efficiency, Dr Geoff Hammond from Bath University. He provided an insight into relevant UK research programmes. The study also benefited from a recent government sponsored literature review conducted by Ricardo AEA.

The initial journal search identified over 190 studies. 52 (27%) of these studies were subject to an initial REA screening. Of these 29 (15%) were codified in the data map.

2.4.5 Trade associations

In light of the tight timescales of the study, only a limited level of industry engagement was possible.19 trade associations were contacted by email. Information was requested on the three research questions.

Of the 19 contacted, circa 25% responded. With majority of the respondents further unstructured phone calls were held, where the nature of the project was discussed. Following these discussions documents were submitted to the team. For each of the 19 trade associations, identified, websites were also reviewed. Where possible studies were then gathered for codification.

Overall 17 papers were subject to an REA review. All of these papers were codified in the data map.

2.5 Summary of data coverage

A summary is provided below on the contribution of each dataset, to the research questions;

Category	Parameter	EUETS	CCA	CRC	ECA	ONS	CHPQA	National Inv	Pollution Inv.	Models	Gov. Publ.	Academic	Trade
Sector	Aggregated cons.	●	●	○		●		●			○	○	
	Site cons./ emissions	●					○		○		○	○	
	Activity	●	●			●					○		
Abatement	Costs		○		○					○	○	○	○
	Performance		○							○	○	○	○
	Penetration		○		○					○	○		
Barriers	Tech. Spec.		○								○	●	○
	Sector. Spec.		○								○	●	○
	Solutions										○		

Key: High quality data - ● Moderate or weak quality data - ○

3. Research Questions

3.1 Research Question 1: Existing (and, where appropriate for context, historic) trends in industrial process energy use

Absolute energy consumption data by sector is of limited value. In order to influence energy efficiency it is important to understand what factors drive energy consumption and the degree to which these are addressable by policymakers.

Deeper data is therefore needed to understand sector performance. This includes having appropriate normalising factors (for example, production level), to monitor efficiency and gathering site-specific data to identify outlier characteristics and performance clusters. The energy end uses need to be understood and, where possible, heat usage and generation requirements should also be considered.

3.1.1 Key sources of data and their limitations

The key data sources along with their associated quality scores are as follows;

EU ETS Annual Submissions			G - Mandatory initiative		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1 (2)	1 (2)	2	1	1
Comment: EU ETS provides annual audited primary information on site energy consumption. EU ETS targets specific activities, which in some instances result in the majority of a particular sector being reported under the scheme. For these sectors coverage is complete, for other sectors coverage will be limited to major combustion processes.					

EU ETS NIMS allocation			G - Mandatory initiative		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1 (2)	1 (2)	2	1	1
Comment: The EU ETS NIMS allocation method for phase III of EU ETS required the collation of site benchmarking information. This exercise captured extensive information on the sites operation. The exercise was only conducted at a single point in time (2012).					

CCA Sector Data			G - Voluntary initiative		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1	1	2	1	1
Comment: CCA's provided biennial audited primary data on sector performance. This has since shifted to an annual frequency. CCA targets specific activities, which in some instances result in the majority of a particular sector being reported under the scheme. For these sectors coverage is complete, for other sectors coverage will be limited. Currently CCA data is only available at an aggregated sector level.					

Energy Consumption in the UK			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1	1	1	1	1
Comment: ECUK provides annual aggregate consumption by fuel type by 4 digit SIC code.					

National Inventory			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1	1	1	1	4
Comment: National Inventory provides annual aggregate emissions data for the UK Includes sector process emissions Subject to extensive audits and controls.					

Sector statistics			O – Trade Association		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1	1	1	3	4
Comment: Sectors (UKSA, CPI) maintain industry statistics on site energy consumption and production volumes. Sector statistics are typically highly restricted.					

Academic Papers			O – Academic		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1	1	1	1	1
Comment: UK academics (Hammond et al. 2012), use EUETS emission data to calculate heat consumption and generation by covered plants.					

3.1.2 Findings

The availability of sector data is not consistent. Broadly sectors can be classed into three groups: well reported (WR), moderately reported (MR) and poorly reported (PR). The data available for each is set out below. For a full list of sectors by allocated group please refer to Annex B.

Table 2: Energy consumption data groups

Factor	**Well reported**	**Moderately reported**	**Poorly reported**
Total consumption	Available	Available	Available
Core process energy consumption	Available	Available	Available
Non-core energy consumption	Available	Available	Available
Non-energy process emissions	Available	Available	Available
Site consumption	Available		
Energy efficiency statistics	Available	Available	
Heat generation (Low quality)	Available		
Heat generation (High quality)	Available		
Heat usage (Low quality)	Available		

Factor	Well reported	Moderately reported	Poorly reported
Heat usage (High quality)	Available		
Activity (market)	Available	Available	Available
Product substitution	Available	Available	

The variation in data coverage is often based on the degree to which a sector activity is regulated under carbon and energy policies. Heavily regulated sectors are required to report energy consumption regularly under a variety of schemes (EU ETS, CCA). These sectors also tend to be the more energy intensive industries and are therefore often the subject of extensive government, industry and academic literature.

The WR group consists mainly of heavy industry. These sectors are typically wholly covered by EU ETS and/or CCAs. Industry trade associations may also independently maintain energy consumption and production statistics by company or site. The combination of robust audited primary data with top-down aggregate statistical datasets, means there are multiple points of triangulation. An example WR sector is the chemical industry (SIC: C20)

MR covers industries that are reasonably energy intensive but are not targeted directly under EU ETS. These sectors will be covered by CCAs, providing reasonably comprehensive biennial audited primary data. The sectors may also have been subject to recent government and/or academic studies on energy performance trends. Site level and heat usage data, however, will not be available. An example MR sector is automotive manufacturing (SIC C29).

The PR sectors are often less energy intensive and also relatively small energy consumers. These sectors will have only limited, if any, regulated consumption. Data for these sectors is only available at aggregate level from Office of National Statistics energy statistics (ECUK). An example PR sector is tobacco manufacturing (SIC C12).

The team estimate that the proportion of energy consumption which is *not covered* by either CCA or EU ETS, is ~15% of total UK industrial energy consumption, as shown in Figure 2 below.

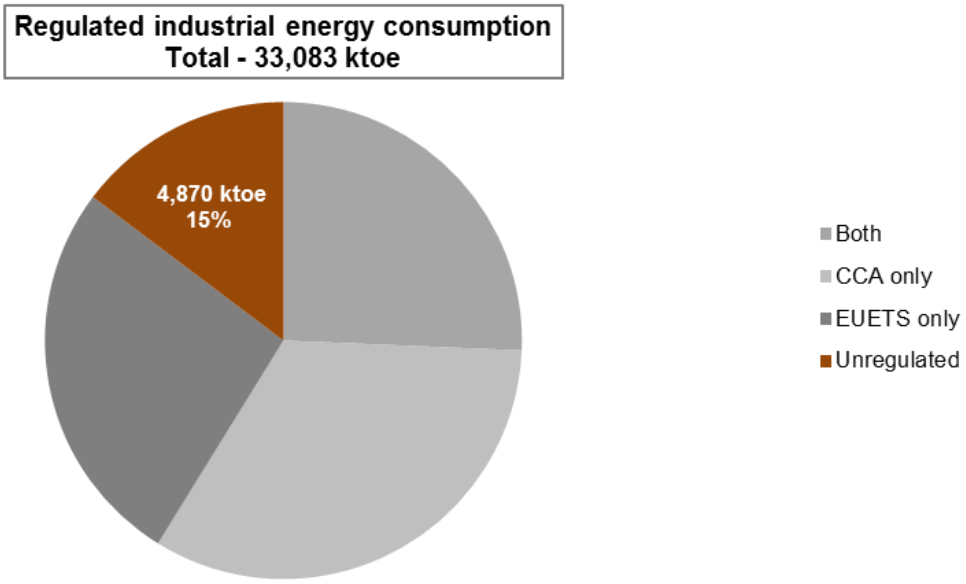


Figure 2: CCA and EUETS regulated energy consumption by sector (adapted from ECUK,2013)

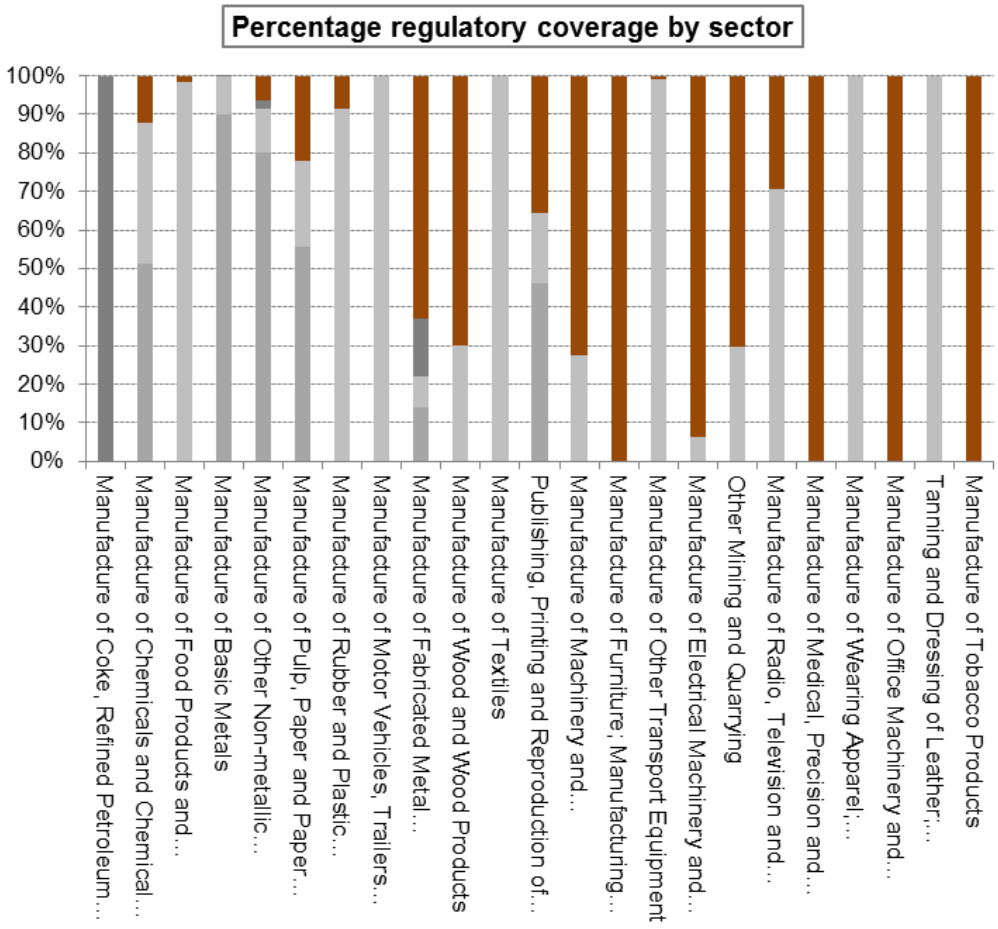


Figure 3: Percentage regulated consumption by sector (adapted from ECUK, 2013)

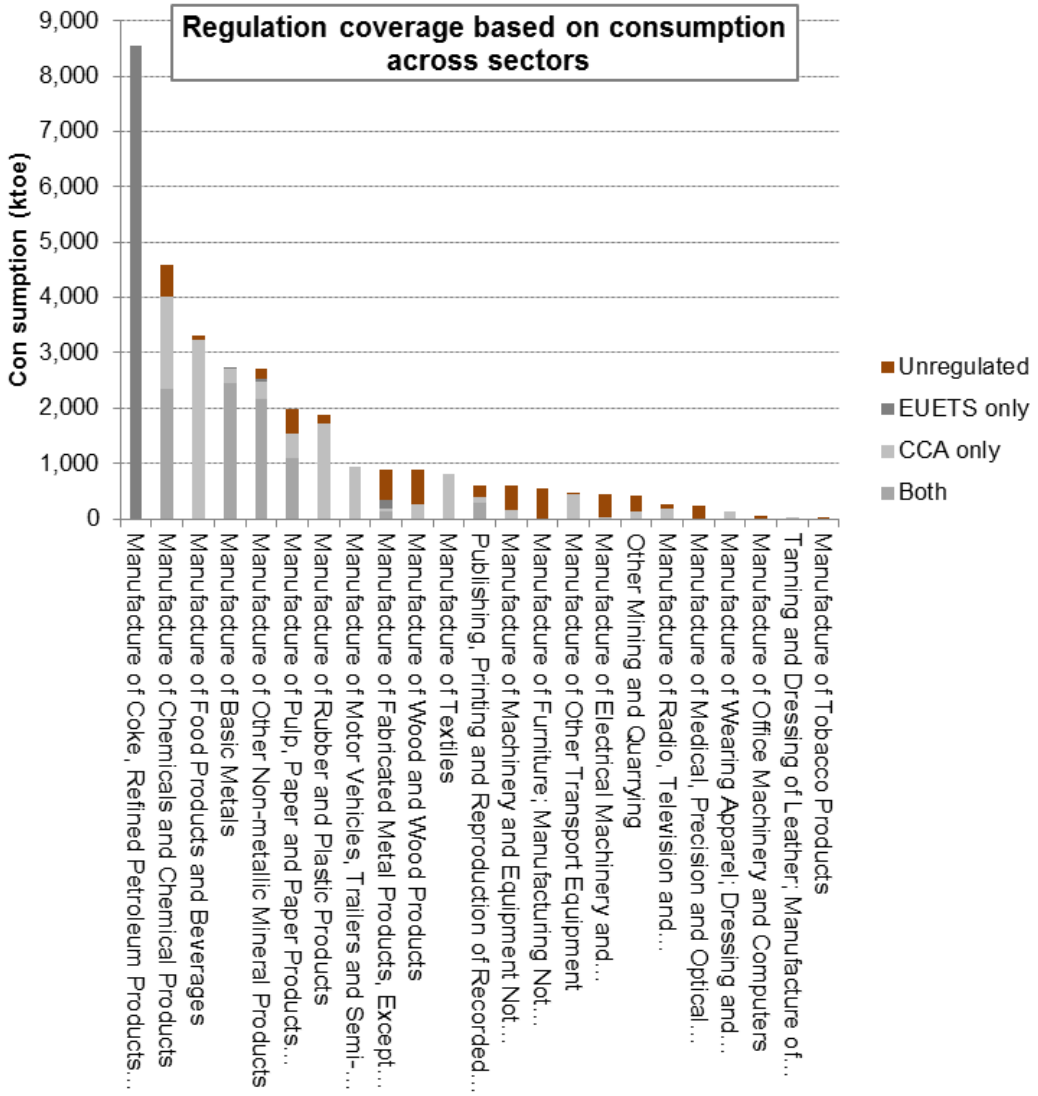


Figure 4: Regulated consumption by sector (adapted from ECUK, 2013)

Regulation coverage is binary, sectors are either covered by policies comprehensively or they are not (Figure 3). Seven sectors have less than 30% of their consumption reported under regulatory schemes. For the remainder the average coverage is ~88%. In absolute terms, the sectors that tend to lower coverage also tend to be the sectors with lower absolute energy consumption (Figure 4).

Regulatory coverage is the critical factor with respect to the quality score. Overall, all the significant energy consuming sectors have a moderate or greater performance in terms of data quality.

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Figure 5: Sector data quality performance (size of box indicates consumption in ktoe, shade of box indicates % regulated consumption with dark being high)

Presenting data quality against additional parameters in the future could be valuable. Significant factors include the number participants or sites in a sector or presenting data quality against different processes as opposed to sectors.

Consider, for instance, the extract below. Many of the heavy industrial sectors are highly consolidated and consist of relatively homogenous operations. Capturing data on energy consumption trends in these sectors is easier and less burdensome than collating data across a large number of diverse operations, such as the food and drinks sector.

Year	Cement	Lime – merchant[a]	Lime – captive[a]	Power stations with FGD	Glass-Works[b]	Fletton brick works	Ammonia
1990	23[c]	11[c]	12	0	33[c]	8	4
1995	23	9	11	1	33[c]	5	4
2000	21	9	11	2	34	3	4
2005	16	9	8	5	32	3	4
2006	16	9	8	5	30	3	4
2007	15	9	8	5	28	3	4
2008	15	9	8	7	26	3	3
2009	13	9	6	8	25	3	3
2010	12	9	6	8	25	2	3
2011	12	9	6	8	25	1	3
Year	Nitric acid	Adipic acid	Steel-works	Electric arc furnaces	Primary aluminium	Other non-ferrous[d]	
1990	8	1	4	20	4	5	
1995	6	1	4	20	4	4	
2000	6	1	4	19	4	3	
2005	4	1	3	12	3	2	
2006	4	1	3	11	3	2	
2007	4	1	3	10	3	2	
2008	4	1	3	8	3	2	
2009	2	1	3	7	3	2	
2010	2	0	2	7	2	2	
2011	2	0	2	7	2	2	

[a] merchant refers to site selling lime and emitting CO_2, captive refers to sites using lime and CO_2 in-situ so no emissions result.
[b] excludes very small glassworks producing lead crystal glass, frits etc.
[c] approximate figures only
[d] large-scale primary production or secondary refining operations only

Figure 6: Extract from "UK Greenhouse Gas Inventory, 1990 to 2011" (p256, DECC,2013)

3.1.3 Summary

There are three groups of sectors; well (WR), moderately (MR) and poorly reported (PR). The data coverage for each is presented below;

The variation in data coverage is often based on the degree to which a sector activity is regulated. The WR group consist mainly of heavy industry, which is regulated by EU ETS and CCAs. MR covers industries that are not covered by EU ETS but are targeted by CCAs. The PR sector is only covered by regulation to a limited degree and therefore data on the sectors will only be available at an aggregate level.

3.2 Research Question 2: Technical and economic energy efficiency potential over the coming decades and resultant carbon emissions reductions

Abatement technology data cannot only cover technology performance. It is important to consider technology costs, current measure penetration, present technology maturity and how all of these factors vary over time. To this end all of the following factors must gathered on opportunities;

- Sector applicability
- Capital costs
- Operational costs
- Cost effective abatement potential
- Theoretical abatement potential
- Current age of plant
- Expected lifetime of plant
- Uptake rates
- Penetration rate
- Technology maturity

Generally abatement data is readily available. The issue is not the sourcing of the values but rather understanding the quality of the data underpinning them.

3.2.1 Sources of data

The key data sources along with their associated quality scores are as follows;

ENUSIM			G - Modelling		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	2	1	2	2	4
Comment: ENUSIM models UK industrial energy efficiency abatement potential. The model considers the majority of UK industrial sectors Model sector parameters have been constructed through industry consultation exercises and expert review The manner in which opportunity data has been gathered means that opportunities that offer rapid payback (within 3 years) are mainly represented					

MARKAL			G - Modelling		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1 (2)	2	1	2	2	4

Comment:

MARKAL models UK energy system dynamics. A module on industrial energy demand is included.

Only heavy industry sectors are modelled explicitly, the remainder are modelled as an aggregate output.

It is believed, but has not been confirmed, that model sector parameters have been constructed through industry consultation exercises and expert review. Model parameters are also derived in part from ENUSIM.

Opportunities are only presented as an aggregate as abatement potential within sectors by process.

POLES			G - Modelling		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1 (2)	3	1	1	1	4

Comment:

POLES models the global energy system. A module on industrial energy demand is included.

As per MARKAL, only heavy industry sectors are modelled explicitly, the remainder are modelled as an aggregate output.

The source data for industrial abatement potential could not be identified.

2050 Pathway Model			G - Modelling		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1 (2)	3	2	2	2	4

Comment:

2050 Pathway Model models UK energy system dynamics. A module on industrial energy demand is included.

Only heavy industry sectors are modelled explicitly, the remainder are modelled as an aggregate output.

Model sector parameters have been constructed through industry consultation exercises and expert review. It is believed that model parameters are also derived in part from MARKAL and ENUSIM.

Opportunities are only presented as an aggregate as abatement potential within sectors by process.

CCA Negotiations			G - Voluntary initiative		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	2	1	2	3	4

Comment:

Climate Change Agreements impose sector energy efficiency targets on industrial sectors. A negotiation process was recently completed to agree targets from 2013 to 2020.

Sectors completed templates which stated theoretical, cost effective and realistic abatement potential by opportunity in 2016 and 2020

Sector differed significantly in the detail of their response. Some sectors did not respond, whilst others provided detailed information.

The data was subject to expert review.

Carbon Trust: Industrial Energy Efficiency Accelerator			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1	2	2	1	3

Comment:

The Industrial Energy Efficiency Accelerator programme investigated abatement potential in several subsectors.

The programme analysed primary site energy data to assess the potential for key technologies by subsector.

Only 13 IEEA studies were completed.

TINA - Industrial Sector			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1	1	1	2	4

Comment:

The TINA programme identified and valued key innovations in the Industrial sector.

Limited number sectors were within the scope of the TINA review. These were primarily heavy industry.

Data for all parameters is drawn from industry consultation, literature review and expert opinion.

Academic Studies			O – Academia		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1 (2)	1 (2)	1 (2)	2	1	1 (4)
Comment: A substantive body of academic literature was identified for industrial energy efficiency (over 190 studies). On a sector by sector basis key papers have been identified that provide additional data abatement. In the UK there are two major academic programmes (PROTEM and UKERC Energy Demand), which provide outputs relating to industrial energy efficiency. The PROTEM project aims 'to promote and disseminate internationally recognised high quality research and support knowledge transfer in process industry energy utilisation to all process industry stakeholders". UKERC Energy Demand is a cross sectoral project assessing energy demand reduction potential in the UK. It is due to report its first outputs in late 2013.					

Industry studies			O - Trade		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1 (2)	1	1	2	3	1 (4)
Comment: Sector activity on energy efficiency varies significantly. For some sectors long term carbon road maps have been developed and large scale technology demonstration programmes whilst for others no industry data has been generated. All the information has been generated from sources, which are not independent.					

3.2.2 Findings

Sectors varied significantly in the degree to which they had been investigated. Two groups emerge; moderately and poorly researched. The characteristics of each are set out below. For a full list of sectors by allocated group please refer to Annex B.

Sources	**Moderately researched**	**Poorly researched**
Government studies	Recent government sponsored primary research into sector abatement potential	No sector specific government studies
Industrial models	Sector explicitly represented	Sector is represented under wider generic aggregates

Sources	Moderately researched	Poorly researched
Academic papers	Extensive academic publications	Limited or no sector specific academic literature
Industry publications	Extensive industry activities including working groups and studies investigating energy efficiency	Limited or no publicised industry activities
Example sector	Manufacturing of basic metals (SIC C24)	Manufacture of basic pharmaceutical products and pharmaceutical preparations (SIC C21)

Moderately research sectors were found to have recent government reports investigating energy efficiency in the sector, explicit modules within economic models to reflect sector characteristics and extensive published industry and academic research. Poorly researched sectors have little if any similar evidence and would often only be modelled under generic aggregate categories within the core modelling tools.

Data quality

Even the datasets for reasonably researched sectors could be significantly improved. Rarely is information based on primary data collection exercises or where it is the findings might be highly context specific or from a single point in time.

The majority of the key data sets (such as the modelling tools used) are constructed or reviewed through industry consultation events and then further calibrated by expert review. Whilst this approach is typical it means it is difficult to determine the accuracy of the parameters. It is also challenging to determine what the error margins on these might be. Furthermore such updates often occur incrementally and can at times not be consistently applied to all aspects of a dataset, often relying heavily on a particular trade association's pro-activeness.

The relevance of a dataset such as capital cost or technology performance is highly context specific. Where studies identify costs or performance the findings might only be relevant for a brief period or to the scenario being considered. Feedback from CCA negotiations observed that abatement potential for some technologies was significantly overstated due to a range of sector specific factors.

There is a subset of sectors for which data quality on abatement potential is high. This is because they have been subject to recent studies, under the Carbon Trust's industrial energy efficiency accelerator programme. These involved extensive site surveys and the gathering of primary information on site and process energy performance.

Comparability of data

Due to a range of factors, it is difficult to readily compare study findings. If this were not the case, it might be possible to construct a reliable evidence base from a patchwork of sources.

The definitions for key technology performance parameters are critical. A distinction is made by some studies on what is theoretically possible and what might be cost effectively achieved in a particular sector. The cost effective abatement performance might also be further adjusted to reflect the realistic potential, where non-economic barriers to uptake are accounted.

In numerous studies technology performance values are provided but with no clarity on which definition these are based. Where they are defined studies they often vary significantly, being based on a range of factors from an opportunities carbon abatement effectiveness to its financial returns by technology types. A number of definitions are set out below

Source	**Theoretical abatement potential**	**Cost effective abatement potential**	**Realistic abatement potential**
AEA, 2012, "Analysing the Opportunities for Abatement in Major Emitting Industrial Sectors"	"The maximum penetration of each abatement option that is technically feasible"	"Options that have a projected abatement cost below the projected carbon price"	"Applies non-economic barriers to uptake [on cost effective abatement potential]"
DECC, 2012,"CCA negotiations"	"The full extent to which a measure could be applied. It only considers technical feasibility and ignores all considerations of cost, risk and logistics"	"The cost of the measure will be paid back through energy savings in six years or less."	"Applies non-economic barriers to uptake [on cost effective abatement potential]"
UCL, 2012, "UK MARKAL Modelling -Examining Decarbonisation Pathways in the 2020s on the Way to Meeting the 2050 Emissions Target"	Not specified	An IRR hurdle rate of 10% is used	Not specified

The potential for a given technology is also dependent on the assumptions regarding the other technologies targeting similar energy efficiency opportunities. For instance, the absolute savings associated with opportunities that reduce heat loss will be affected if an efficient heat generating plant has been implemented. This is often referred to as modelling the impact of "sequential implementation".

Often technology attributes are presented as percentages. This is typically used to express sector applicability, uptake rates or technology penetration constraints. Comparing percentage data across studies is difficult. Indeed it is only truly possible where baselines and study scope are mirrored.

Data is also often aggregated for opportunities or sectors. Studies often aggregate abatement potential across multiple opportunities. Models will aggregate the data across a number smaller sectors. They use a generic "Other Industries" category to represent these.

Industrial energy abatement models typically focus on heavy industry. Model coverage is set out below. ENUSIM offers the most detailed representation of the sectors.

Table 3: Sector representation within models (R = represented, A = aggregated, N = explicitly not included)

Sector	ENUSIM	MARKAL	POLES	2050 Pathway
C10 Manufacture of Food Products	R	A	A	A
C11 Manufacture of beverages	R	A	A	A
C12 Manufacture of tobacco products	A	A	A	A
C13 Manufacture of textiles	R	A	A	A
C14 Manufacture of wearing apparel	A	A	A	A
C15 Manufacture of leather and related products	R	A	A	A
C16 Manufacture of wood and of products of wood and cork except furniture manufacture of articles of straw and plaiting materials	A	A	A	A
C17 Manufacture of paper and paper products	R	R	A	A
C18 Printing and reproduction of recorded media	R	A	A	A
C19 Manufacture of coke and refined petroleum products	**N**	A	A	A
C20 Manufacture of chemicals and chemical products	R	R	R	R
C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	A	A	A	A
C22 Manufacture of rubber and plastic products	R	A	A	A
C23 Manufacture of other non-metallic mineral products	R	R	R	R
C24 Manufacture of basic metals	R	R	R	R
C25 Manufacture of fabricated metal products except machinery and equipment	R	A	A	A

Sector	ENUSIM	MARKAL	POLES	2050 Pathway
C26 Manufacture of computer electronic and optical products	R	A	A	A
C27 Manufacture of electrical equipment	A	A	A	A
C28 Manufacture of machinery and equipment n e c	A	A	A	A
C29 Manufacture of motor vehicles trailers and semi-trailers	R	A	A	A
C30 Manufacture of other transport equipment	R	A	A	A
C31 Manufacture of furniture	R	A	A	A
C32 Other manufacturing	A	A	A	A

Where study outputs are produced on a normalised basis, this can also add uncertainty. Capital cost, for instance, might be expressed as £2,000 m/PJ per annum (MARKAL), or €/tCO_2. Comparison from such sources is complicated by the assumptions that will govern each of the variables. For instance, a marginal abatement cost (£/tCO_2) will be dependent on currency, inflation, capital and operational cost data and discount factors adopted for the net present value calculation and the assumed carbon factors and opportunity fuel savings for the lifetime emission savings.

Penetration rates

Primary data on technology penetration and uptake rates is lacking. Generally information on these factors is constructed using either industry consultation exercises or via expert review. Examples include recent CCA negotiations and model calibrations, such as ENUSIM and MARKAL. Whilst this is a typical approach to conducting such reviews, it does mean that such assessments are made in the absence of significant sources of primary data.

Not only are the values themselves derived with a lack of primary evidence, there is also little if any information in the public domain on the justification for any changes made. As a result, where changes have occurred it is difficult to determine the reasons for the amendment. It is also challenging to confirm the negative. Has a value remained the same because it should stay the same or because the industry in question was not represented at the stakeholder event?

The combination of the above i.e. lack of primary data and limited recording of the process, means that it is difficult to assign the values derived with a high quality score. A more robust method was demonstrated in an evaluation of Enhanced Capital Allowances. This included a survey of businesses participating in the scheme. It captured primary data on implementation of technologies by sector. Such an initiative provides not only valuable information on a scheme's success but also important

data on implementation rates by sectors and company size and also potential information on capital costs of technologies.

Uptake rate gradients are currently typically modelled as s-curves based on normal distribution. The available literature on how uptake rates are influenced is limited. Typically measure uptake is therefore calculated by reference to a maximum possible factor and from this an S-curve penetration plot is produced.

3.2.3 Summary

Sectors differ in the degree to which they have been investigated. Two categories have been identified; moderately researched and poorly researched. Their characteristics are defined below;

Sources	**Moderately researched**	**Poorly researched**
Government studies	Recent government sponsored primary research into sector abatement potential	No sector specific government studies
Industrial models	Sector explicitly represented	Sector is represented under wider generic aggregates
Academic papers	Extensive academic publications	Limited or no sector specific academic literature
Industry publications	Extensive industry activities including working groups and studies investigating energy efficiency	Limited or no publicised industry activities
Example sector	Manufacturing of basic metals (SIC C24)	Manufacture of basic pharmaceutical products and pharmaceutical preparations (SIC C21)

Even the datasets for reasonably researched sectors could be significantly improved. Rarely is information based on primary data collection exercises or where it is the findings might be highly context specific or from a single point in time.

Due to a range of factors (definitions, aggregated outputs, inconsistent baselines etc.), it is difficult to readily compare study findings. If this were not the case, it might be possible to construct a reliable evidence base from a patchwork of sources.

Primary data on technology penetration and uptake rates is lacking. Generally information on these factors is constructed using either industry consultation exercises or via expert review. Not only are the values themselves derived with a lack of primary data, there is also little, if any, information in the public domain on the justification for any changes made. The combination of the lack of primary data and limited recording of the process, means that it is difficult to assign the values derived with a high quality score.

3.3 Research Question 3: Barriers to uptake of energy efficiency improvements

Understanding the impact of barriers is essential to the design of effective energy efficiency policy. Unless it is clear what the inhibiting factors to technology uptake are, it is difficult to determine what the appropriate instrument should be.

In spite of their importance, barriers remain an area that is poorly understood. While there is a significant body of works covering the typology of barriers, there are only a limited number of studies that quantify the impact of different effects.

3.3.1 Sources of data

The key data sources along with their associated quality scores are as follows.

Decarbonisation of heat in industry			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
4	1	1	1	1	4
Comment: A recent literature review of 527 studies focused on the major heat consuming industries. Identified qualitative statements on barriers to energy efficiency by sector. No studies were identified which quantified the impact of barriers or enablers.					

Industrial Energy Efficiency Accelerator			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
4	2	2	2	1	3
Comment: The Carbon Trust's Industrial Energy Efficiency Accelerator programme investigated abatement potential in several subsectors. The programme analysed primary site energy data to assess the potential for key technologies by subsector. For each sector barriers to energy efficiency were identified but not quantified. Findings were supported by sector surveys on energy efficiency barrier significance. Only 13 IEEA studies were completed.					

TINA - Industrial Sector			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
4	2	1	1	2	4

Comment:
The TINA programme identified and valued key innovations in the Industrial sector.
Limited number sectors were within the scope of the TINA review. These were primarily heavy industry.
Data for all parameters is drawn from industry consultation, literature review and expert opinion. Barriers are qualitatively appraised by sector and technology.

Capturing the full electricity potential of the UK			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
4	2	2	1	1	3
Comment:					
Study funded on behalf of DECC to determine the electricity demand reduction potential in UK.					
Interviews undertaken in Commercial and Industrial sector with findings being presented as an aggregate.					
An order of barriers was established but their impact was not quantified.					

2050 Pathway Analysis			G - Publicly funded study		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
4	3	2	2	2	4
Comment:					
2050 Pathway analysis models UK energy system dynamics. A module on industrial energy demand is included.					
Only heavy industry sectors are modelled explicitly, the remainder are modelled as an aggregate output.					
Model sector parameters have been constructed through industry consultation exercises and expert review.					
A commentary of barriers affecting the key modelled industrial sectors is presented.					

ENUSIM			G - Modelling		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1 (2)	2	1	2	2	4
Comment:					
ENUSIM models UK industrial energy efficiency abatement potential.					
The model considers the majority of UK industrial sectors					
Model sector parameters have been constructed through industry consultation exercises and expert review					
The manner in which opportunity data has been gathered means that opportunities that offer rapid payback (within 3 years) are mainly represented					

Model provides quantified estimates of hidden costs for measure types. The data for these opportunities was derived from sector experts.

The model also allows for modelling based on a number of discount rates. This can be used as a proxy for some financial barriers.

CCA Negotiations			G - Voluntary initiative		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
2	2	1	2	3	4

Comment:

Climate Change Agreements impose sector energy efficiency targets on industrial sectors. A negotiation process was recently completed to agree targets from 2013 to 2020.

Sectors completed templates which stated theoretical, cost effective and realistic abatement potential by opportunity in 2016 and 2020

Sectors differed significantly in the detail of their response.

Sectors were requested to justify any significant deviation between cost effective and realistic abatement potential.

The data was subject to expert review.

Academic studies – typologies of barriers			O - Academia		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
4	1	1	1	1	4

Comment:

A substantive body of academic literature was identified for industrial energy efficiency (over 190 studies).

A number of academic papers define approaches towards barrier and enabler typology.

The UKERC Energy Demand is a cross sectoral project assessing energy demand reduction potential in the UK. It is due to report its first outputs in late 2013. Within the programme, one of the research streams is targeting barriers to energy demand reduction.

An example of a comprehensive recent study would be; “E. Cagno et al., 2013, A novel approach for barriers to industrial energy efficiency”

Academic studies – quantification of barriers			O - Academia		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
1	1	3	1	1	2

Comment:

A substantive body of academic literature was identified for industrial energy efficiency (over 190 studies).

A limited number of academic papers have quantified the effects of barriers on energy efficiency measure uptake.

The UKERC Energy Demand is a cross sectoral project assessing energy demand reduction potential in the UK. It is due to report its first outputs in late 2013. Within the programme, one of the research streams is targeting barriers to energy demand reduction.

None of the studies have conducted the analysis on an industrial sector.

Industry studies			O - Trade		
Maryland Ranking Scale	Scale/Robustness of Coverage	Representative	Quality of Research Delivery	Level of independence from Delivery Body	Source of data
4	1	1	1	3	4

Comment:

Sector activity on energy efficiency varies significantly. For some sectors long term carbon road maps have been developed and large scale technology demonstration programmes whilst for others no industry data has been generated.

All the information has been generated from sources, which are not independent.

Typically sector report will consider the barriers to energy efficiency and qualitatively comment on their significance.

Some sectors consider the role of their products as enabler for energy efficiency i.e. Steel sector in "EUROFER, 2013, A Steel Roadmap for a Low Carbon Europe 2050"

3.3.2 Findings

Overall, the quality of data on barriers to energy efficiency is weak. Whilst there is extensive literature available on the types of barriers and how they manifest in the industrial sectors, these studies do not quantify the impact of barriers. The only papers which have attempted to quantify these effects have primarily targeted non-energy intensive sectors (property, retail for instance), with a small number of exceptions.

Variance by sectors

Sectors vary in the degree to which sector specific barriers have been explored. In a similar vein to the abatement evidence base, those sectors that have been subject to extensive government, industry and academic research will often include within these papers, lists of significant barriers affecting the industry. The remaining sectors will have little if any direct commentary on sector barriers.

Quantification of the impact of barriers

In the UK there are two current sources, which provide quantified data on the impact of barriers; ENUSIM and CCA negotiations.

In 2008, an exercise was completed to incorporate hidden costs within ENUSIM. The data was based on estimates developed by Enviros and then subject to review by AEA, Ecofys and the Carbon Consortium. All of these firms are respected major energy consultancies and/or technical experts in energy efficiency modelling. The final values adopted for ENUSIM were subject to a limited industry consultation exercise. To this end, hidden costs have been reasonably thoroughly represented and the impact of these barrier can be quantified through comparison of cost effective abatement potential and realistic abatement potential.

		High Energy Intensive Industry		Low Energy Intensive Industry		Units
Hidden Cost	**Split of Measure**	**Low**	**High**	**Low**	**High**	
Project identification	Behavioural	3	5	6	10	Hrs
	Engineering Measures	3	5	6	10	Hrs
	Non-engineering measures	3	5	6	10	Hrs
Project appraisal	No cost	0	0	0	0	Hrs
	Low cost	20	40	10	30	Hrs
	High cost	50	100	40	80	Hrs
Project commissioning	No Cost	1	5	1	5	Of capital costs
	Low Cost	3	6	3	6	Of capital costs
	High cost	1	5	1	5	Of capital costs
Production Disruption	Behavioural	0%	0%	0%	0%	Of capital costs
	Engineering Measures	0%	5%	0%	5%	Of capital costs
	Other Measures	0%	5%	0%	5%	Of capital costs
Additional Engineering	Behavioural	5%	10%	0%	5%	Of capital costs
	Engineering Measures	5%	10%	0%	5%	Of capital costs
	Other Measures	5%	10%	0%	5%	Of capital costs
Risk of Delivery	Behavioural	-10%	-20%	-10%	-20%	Of energy savings
	Engineering Measures	-5%	-10%	-5%	-15%	Of energy savings
	Other Measures	-10%	20%	10%	20%	Of energy savings
Ongoing Management	Behavioural	6	12	6	12	hrs/yr
	Engineering Measures	6	12	6	12	hrs/yr
	Other Measures	12	60	12	60	hrs/yr

Figure 7: Extract from AEA, 2008 showing the method for accounting for hidden costs

The recent CCA negotiations also provide aggregated technology specific data on barriers. Respondent provided quantitative estimates of realistic abatement potential by technology and were allowed to expand on these issues further in the response. It should be noted, however, that not all sectors responded to the request for evidence and the sophistication of responses also varied significantly.

In order to allow respondents to easily and practically provide information on barriers by technology only a single quantified realistic abatement potential figure was requested. The weakness with this approach is that the effect of different barriers on a technology could not be isolated. The dataset is also prone to industry bias.

In spite of all of these weaknesses it should still be considered a valid source of recent survey data on the industry's view of technology abatement potential and the barriers constraining it.

COL B Abatement Measure	COL J Full Technical potential penetration by 2016 (%)	COL K Full Technical potential penetration by 2020 (%)	COL L Payback Period Cost Effective (years)	COL M Full Cost effective potential penetration by 2016 (%)	COL N Full Cost effective potential penetration by 2020 (%)	COL O Payback Period Realistic (years)	COL P Realistic potential penetration by 2016 (%)	COL Q Realistic potential penetration by 2020 (%)

Figure 8: Extract of Climate Change Agreement pro forma negotiations

Internationally there have been a number of substantial studies which have analysed large scale energy efficiency programmes to derive statistical relationships between company, site and sector attributes and the implementation of energy efficiency measures. Whilst the majority of these have focused on non-energy intensive sectors, some of the findings may be appropriate reference points for UK approaches.

As an example, DeCanio in 2008, undertook a review of data held against the US Environmental Protection Agency's voluntary pollution prevention programme, Green Lights. He notes in his introduction that not only have these programmes served to driver energy efficiency but that they have also begun "to generate a great deal of new information".

DeCanio explored two categories of barriers; economic and organisational variables. A list of the attributes investigated is included on the following page. Using the dataset he was able to conclude statistically significant relationships between organisational size and type and their willingness to invest in energy efficiency.

The effect of enablers

The research on enabling factors is even more limited than that on barriers. The lack of information has been noted by a number of academics and no comprehensive studies could be identified.

3.3.3 Summary

Within the qualitative literature, sectors vary in the degree to which sector specific barriers have been explored. In a similar vein to the abatement evidence base, those sectors that have been subject to extensive government, industry and academic research will often include within these papers, lists of significant barriers affecting the industry. The remaining sectors will have little if any direct commentary on sector barriers.

In the UK there are two current sources, which quantify elements of barriers; ENUSIM and CCA negotiations. In ENUSIM, hidden costs have been reasonably thoroughly represented and the impact of these barrier can be quantified. The recent CCA negotiations also provide aggregated technology specific data on barriers. In spite of the weaknesses (limited coverage, high industry bias) it should still be considered a valid source of recent survey data on the industry's view of technology abatement potential and the barriers constraining it.

Internationally there have been a number of substantial studies which have analysed large scale energy efficiency programmes to derive statistical relationships between company, site and sector attributes and the implementation of energy efficiency measures.

The research on enabling factors is even more limited than that on barriers. The lack of information has been noted by a number of academics and no comprehensive studies could be identified.

4. Considerations for Phase 2

4.1 Data sets from current schemes

4.1.1 Climate Change Agreements P10 forms:

Currently Climate Change Agreement data is restricted to aggregate sector submissions. This data provides government with an insight into sector level energy efficiency trends. It does not, however, provide information about site-specific performance.

Annually CCA participants must complete a P10 tax return form. This allows firms to claim relief on the Climate Change Levy. This data provides annual total site and CCA covers fuel consumption data for all participants.

If this data could be made available it would provide DECC with a high quality, detailed database of energy consumption for a significant proportion of UK industrial energy consumption (19,460ktoe or 59%). This could allow for:

- Site benchmarking
- Validation of further energy datasets, eg: NEED (see below)
- Improve understanding of wider auxiliary consumption across sectors

It should be noted however that this data is collected for specific tax purposes. It may therefore not be appropriate or possible to use this information for any other purpose.

4.1.2 Enhanced Capital Allowances:

Enhanced Capital Allowances allow businesses to claim a higher level of capital allowance for expenditure on certain energy efficiency measures. Currently businesses only submit an aggregate capital expenditure value on a tax return. As a result this value is of limited use in terms of estimating expenditure on energy saving measures, possibly only providing a coarse indicator of energy efficiency investment trends.

There are a number of means by which ECA data could be gathered. Firms using the scheme could submit additional information, either mandatorily or voluntarily, regarding their investments. Alternatively, a tele-surveying exercise could be conducted on applicants.

Either of the above methods would provide a valuable insight into energy efficiency behaviour. It could allow for:

- Statistical analysis of factors affecting technology uptakes
- Capital cost data on technology types
- Penetration data on technology types

It should be noted however, that this data is collected for specific tax purposes. It may therefore not be appropriate or possible to use this information for any other purpose.

4.2 Data sets from emerging schemes

4.2.1 Energy savings opportunity scheme:

The energy savings opportunity scheme is being implemented to meet the UK's EU obligations under Article 8 of the Energy Efficiency Directive. The policy requires that large firms undertake energy audits.

The scheme is currently under consultation. Not only are the energy efficiency obligations on firms being considered but also the manner in which data is to be reported is under review. If firms are required to centrally report data, this may be of value for the industrial energy efficiency evidence base.

It should be noted that ESOS has a similar scope to CRC, ie: it targets companies at the parent level. To date this has meant that CRC data has only been of limited value to the industrial energy efficiency evidence base. Values are too difficult to disaggregate meaningfully from the parent company. If the same approach is used for ESOS, then it may be difficult to isolate industrial energy efficiency data.

4.2.2 Carbon roadmaps:

Carbon roadmaps will be developed for a number of industrial sectors. These will determine how 2050 carbon reduction targets will be achieved.

These studies will provide comprehensive reviews of abatement potential. They will include an appraisal of relevant sector literature and will compile primary data through site audits. The studies will potentially deliver:

- Data on measured performance;
- Independent data on measured penetration; and
- A consistent method of quantifying abatement potential for a number of major sectors.

4.2.3 Electricity demand reduction pilots:

The electricity demand reduction pilots are due to be implemented in 2014. They will attempt to demonstrate how demand reduction measures might be permanently implemented and become tradable through the capacity market mechanism.

If pilots are trialled in the energy intensive sectors, they may provide detailed electricity consumption data for the sites concerned. The pilots could provide:

- A demonstration of technology performance;
- An estimate of the scope for industrial electricity demand reduction measures; and
- An insight into the barriers for electricity demand reduction.

4.2.4 NEED:

NEED combines utility billing data with valuation office agency asset classifications. Currently the scheme is being trialled in the domestic and non-energy intensive commercial sectors.

The project could be expanded to the industrial sectors once initial methodological issues have been overcome. If this were possible, the scheme could provide:

- A further point of triangulation between other datasets on energy consumption data
- Potentially a link to half hourly metered data by site allowing for profile analysis

4.2.5 UKERC: Energy Demand:

A major consortium of leading UK universities is currently undertaking a substantial programme investigating opportunities for reducing energy demand.

It will include wider ranging studies into the barriers affecting energy efficiency as well as focused analysis on the abatement potential within UK industry. The first outputs from the programme are expected in winter 2013/14.

The project could potentially deliver information on:

- Industrial energy efficiency abatement potential
- Primary cross-sectoral data on the impacts of barriers and enablers on energy efficiency

5. Conclusions

5.1 Phase 1 findings

- Overall the evidence base is patchy. There is significant variation in the quality and coverage of data between sectors.
- Energy trends are well understood in regulated large consuming sectors but poorly understood in unregulated small consuming sectors.
- Abatement potential data is at best moderate. There is limited primary data available for many of the key parameters. There are also great difficulties in comparing datasets and studies meaning that adopting a patchwork approach to gap filling is hindered.
- Data on barriers is often restricted to qualitative appraisals. International studies provide useful precedents, however, on how to improve evidence, often relying on data gathered through wider energy efficiency programmes.
- There are a number of emerging initiatives and academic programme which could offer significant improvements in data over next 2 – 3 years. This includes UKERC Energy Demand project, which is being led by a number of the leading academic institutions in the UK and government funded research, such as the carbon road maps.
- There may also be scope for new useful data to be derived from existing schemes, such as CCAs and ECAs. CCAs could provide additional information on site energy performance in a sector, whilst ECAs could provide information on technology uptake rates.

Research Question 1: What are the existing (and, where appropriate for context, historic) trends in industrial process energy use?

There are three groups of sectors; well (WR), moderately (MR) and poorly reported (PR). The data coverage for each is presented below;

Factor	Well reported	Moderately reported	Poorly reported
Total consumption	Available	Available	Available
Core process energy consumption	Available	Available	Available
Non-core energy consumption	Available	Available	Available
Non-energy process emissions	Available	Available	Available
Site consumption	Available		
Energy efficiency statistics	Available	Available	
Heat generation (Low quality)	Available		
Heat generation (High quality)	Available		

Factor	Well reported	Moderately reported	Poorly reported
Heat usage (Low quality)	Available		
Heat usage (High quality)	Available		
Activity (market)	Available	Available	Available
Product substitution	Available	Available	

The variation in data coverage is often based on the degree to which a sector activity is regulated. The WR group consist mainly of heavy industry, which is regulated by EU ETS and CCAs. MR covers industries that are not covered by EU ETS but are targeted by CCAs. The PR sector is only covered by regulation to a limited degree and therefore data on the sectors will only be available at an aggregate level.

Research Question 2: What is the technical and economic energy efficiency potential over the coming decades and resultant carbon emissions reductions?

Sectors differ in the degree to which they have been investigated. Two categories have been identified; moderately researched and poorly researched. Their characteristics are defined below;

Sources	Moderately researched	Poorly researched
Government studies	Recent government sponsored primary research into sector abatement potential	No sector specific government studies
Industrial models	Sector explicitly represented	Sector is represented under wider generic aggregates
Academic papers	Extensive academic publications	Limited or no sector specific academic literature
Industry publications	Extensive industry activities including working groups and studies investigating energy efficiency	Limited or no publicised industry activities
Example sector	Manufacturing of basic metals (SIC C24)	Manufacture of basic pharmaceutical products and pharmaceutical preparations (SIC C21)

Even the datasets for reasonably researched sectors could be significantly improved. Rarely is information based on primary data collection exercises or where it is the findings might be highly context specific or from a single point in time.

Due to a range of factors (definitions, aggregated outputs, inconsistent baselines etc.), it is difficult to readily compare study findings. If this were not the case, it might be possible to construct a reliable evidence base from a patchwork of sources.

Primary data on technology penetration and uptake rates is lacking. Generally information on these factors is constructed using either industry consultation exercises or via expert review. Not only are the values themselves derived with a lack of primary data, there is also little, if any, information in the public domain on the justification for any changes made. The combination of the lack of primary data and limited recording of the process, means that it is difficult to assign the values derived with a high quality score.

Research Question 3: What are the barriers to uptake of energy efficiency improvements?

Within the qualitative literature, sectors vary in the degree to which sector specific barriers have been explored. In a similar vein to the abatement evidence base, those sectors that have been subject to extensive government, industry and academic research will often include within these papers, lists of significant barriers affecting the industry. The remaining sectors will have little if any direct commentary on sector barriers.

In the UK there are two current sources, which quantify elements of barriers; ENUSIM and CCA negotiations. In ENUSIM, hidden costs have been reasonably thoroughly represented and the impact of these barrier can be quantified. The recent CCA negotiations also provide aggregated technology specific data on barriers. In spite of the weaknesses (limited coverage, high industry bias) it should still be considered a valid source of recent survey data on the industry's view of technology abatement potential and the barriers constraining it.

Internationally there have been a number of substantial studies which have analysed large scale energy efficiency programmes to derive statistical relationships between company, site and sector attributes and the implementation of energy efficiency measures.

The research on enabling factors is even more limited than that on barriers. The lack of information has been noted by a number of academics and no comprehensive studies could be identified.

5.2 Considerations for Phase 2

Through future schemes

ESOS is currently under consultation. If firms are required to centrally report data under the scheme, this may be of value for the industrial energy efficiency evidence base. It should be noted, however, that ESOS has a similar scope to CRC, a scheme where industrial energy data has been difficult to isolate.

Carbon roadmaps will be developed for a number of industrial sectors. These will determine how 2050 carbon reduction sector targets will be achieved. The studies will potentially deliver:

- Data on measured performance
- Independent data on measured penetration
- A consistent method of quantifying abatement potential for a number of major sectors

The electricity demand reduction pilots are due to be implemented in 2014. The pilots could provide:

- A demonstration of technology performance
- An estimate of the scope for industrial electricity demand reduction measures
- An insight into the barriers for electricity demand reduction

NEED combines utility billing data with valuation office agency asset classifications. The project could be expanded to the industrial sectors once initial methodological issues have been overcome. If this were possible, the scheme could provide:

- A further point of triangulation between other datasets on energy consumption data
- Potentially a link to half hourly metered data by site allowing for profile analysis

UKERC Energy Demand programme is a programme involving the leading UK universities. It is investigating opportunities for reducing energy demand. The first outputs from the programme are expected in winter 2013/14.The project could potentially deliver information on:

- Industrial energy efficiency abatement potential
- Primary cross-sectoral data on the impacts of barriers and enablers on energy efficiency

Through current schemes

If data form P10 CCA forms were made available it would provide DECC with a high quality detailed database of energy consumption for a significant proportion of UK industrial energy consumption (19,460ktoe or 59%). This could allow for:

- Site benchmarking
- Validation of further energy datasets i.e. NEED
- Improve understanding of wider auxiliary consumption across sectors

ECA data could provide a valuable insight into energy efficiency behaviour. It could allow for:

- Statistical analysis of factors affecting technology uptakes
- Capital cost data on technology types
- Penetration data on technology types

It should be noted however that data from both schemes is collected for specific tax purposes. It may therefore not be appropriate or possible to use this information for any other uses.

Annex A: Codification method

Code	Fit for our purpose (relevance)	Adapted Maryland rating	Research design quality		Quality of research delivery	Independence of study from delivery	Source of data
			Scale/robustness in terms of coverage	Representative?			
1	All aspects are relevant to our objectives	Quantified direct impacts (e.g. measures installed)	Total industry	Comprehensive representation of target group (Census)	Conducted in line with good practice (ISO20252 or similar) or subject to independent peer review	Independent study	Primary auditted data
2	Some aspects are relevant to our objectives	Quantified as part of an aggregate	Sample-based research/evaluation	Randomly selected sample, representative of the population (Limited or no bias)	Subject to internal peer review and commissioned by third party	Some aspects are independent	Primary data
3	Limited relevance to our objectives	Partially quantified	Case study approach	Sample selection is non-random and may not be representative of the population (either through non-random design or bias e.g. non-response bias)	Steps taken to ensure quality either not undertaken or not reported	Non-independent study	Primary and secondary data
4		Qualitatively appraised					Secondary data

Annex B: Research question groupings

The list below is reference for the groupings allocated by sector;

Table 4: Quality of evidence with respect to the research questions (WR = Well reported, MR = Moderately reported, PR = Poorly reported)

Sector	RQ 1	RQ 2	RQ 3
C10 Manufacture of Food Products	MR	MR	MR
C11 Manufacture of beverages	MR	MR	MR
C12 Manufacture of tobacco products	PR	PR	PR
C13 Manufacture of textiles	MR	MR	MR
C14 Manufacture of wearing apparel	MR	PR	PR
C15 Manufacture of leather and related products	MR	MR	MR
C16 Manufacture of wood and of products of wood and cork except furniture manufacture of articles of straw and plaiting materials	PR	PR	PR
C17 Manufacture of paper and paper products	WR	MR	MR
C18 Printing and reproduction of recorded media	MR	MR	MR
C19 Manufacture of coke and refined petroleum products	WR	MR	MR
C20 Manufacture of chemicals and chemical products	WR	MR	MR
C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	PR	PR	PR
C22 Manufacture of rubber and plastic products	MR	MR	MR
C23 Manufacture of other non metallic mineral products	WR	MR	MR
C24 Manufacture of basic metals	WR	MR	MR
C25 Manufacture of fabricated metal products	MR	MR	MR

Sector	RQ 1	RQ 2	RQ 3
except machinery and equipment			
C26 Manufacture of computer electronic and optical products	MR	PR	PR
C27 Manufacture of electrical equipment	MR	PR	PR
C28 Manufacture of machinery and equipment n e c	PR	PR	PR
C29 Manufacture of motor vehicles trailers and semi trailers	MR	MR	MR
C30 Manufacture of other transport equipment	MR	MR	MR
C31 Manufacture of furniture	PR	PR	PR
C32 Other manufacturing	PR	PR	PR

Where the definitions by research question were as follows;

Research Question 1: What are the existing (and, where appropriate for context, historic) trends in industrial process energy use?

Factor	Well reported	Moderately reported	Poorly reported
Total consumption	Available	Available	Available
Core process energy consumption	Available	Available	Available
Non-core energy consumption	Available	Available	Available
Non-energy process emissions	Available	Available	Available
Site consumption	Available		
Energy efficiency statistics	Available	Available	
Heat generation (Low quality)	Available		
Heat generation (High quality)	Available		
Heat usage (Low quality)	Available		
Heat usage (High quality)	Available		
Activity (market)	Available	Available	Available

Factor	Well reported	Moderately reported	Poorly reported
Product substitution	Available	Available	

Research Question 2: What is the technical and economic energy efficiency potential over the coming decades and resultant carbon emissions reductions?

Sources	Moderately researched	Poorly researched
Government studies	Recent government sponsored primary research into sector abatement potential	No sector specific government studies
Industrial models	Sector explicitly represented	Sector is represented under wider generic aggregates
Academic papers	Extensive academic publications	Limited or no sector specific academic literature
Industry publications	Extensive industry activities including working groups and studies investigating energy efficiency	Limited or no publicised industry activities

Research Question 3: What are the barriers to uptake of energy efficiency improvements?

Within the qualitative literature, sectors vary in the degree to which sector specific barriers have been explored. In a similar vein to the abatement evidence base, those sectors that have been subject to extensive government, industry and academic research will often include within these papers, lists of significant barriers affecting the industry. The remaining sectors will have little if any direct commentary on sector barriers.

Annex C: Sector Data

For each sector the available data is considered below, along with the datasets respective quality.

C10 Manufacture of food products

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	IEEA sector guides[1], , TINA, National inventory, ENUSIM, MARKAL, POLES, ECUK, Hammond and Norman (2012)
	Core process energy consumption	Medium	EUETS annual submission, NIMS allocation process, CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	There are no significant non-energy process emissions
	Energy efficiency data for sector	High	IEEA sector guides, CCA sector negotiations, CCA sector submissions, Hammond *et al*. (2009), Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process, Hammond *et al*. (2009)
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway

[1] IEEA sector guides under the food products sector are dairy, animal feed, confectionary stoving and industrial baking.

Research question	Factor	Quality	Source
			analysis, EUETS annual submission, NIMS allocation process
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	Medium	IEEA sector guides, TINA, ENUSIM
	Capital costs	High	IEEA sector guides, CCA sector negotiations, TINA, ENUSIM, ECA, MARKAL, Centre for Low Carbon Futures (2011)
	Operational costs	Medium	MARKAL, IEEA Animal Feed sector guide, ENUSIM
	Expected life time of plant	Medium	IEEA Paper sector guide, CCA sector negotiations, ECA, MARKAL, ENUSIM
	Technology maturity	Low	IEEA sector guides, TINA
	Penetration / uptake rate	Medium	IEEA Paper sector guide, CCA sector negotiations, TINA, ENUSIM, ECA,
	Age profile of current plant	Medium	TINA, MARKAL, ENUSIM
	Cost effective abatement performance	High	AEA (2010), CCA sector negotiations, 2050 pathways analysis, POLES, ECA, MARKAL, Centre for Low Carbon Futures (2011)
	Technical abatement performance	High	Dairy Roadmap (DSCF), IEEA sector guides, AEA (2010), CCA sector negotiations, TINA, MARKAL, SERPEC-CC (2009), ENUSIM, Hammond and Norman (2012), McKenna and Norman (2010), Pereira and Vincente (2010)
Barriers	Sector specific barriers	Low	Dairy Roadmap (DSCF), IEEA sector guides, TINA, 2050 pathways analysis, Centre for Low Carbon Futures (2011)
	Sector specific enablers	Low	Dairy Roadmap (DSCF), IEEA sector guides, 2050 pathways analysis, Centre for Low Carbon

Research question	Factor	Quality	Source
			Futures (2011), Sandberg and Söderström (2003)
	Technology specific barriers	Low	IEEA sector guides, TINA, CCA sector negotiations, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the food manufacture sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions and the EU ETS. Data on heat generation and consumption can also be derived from EU ETS annual data and was also submitted, as one off exercise, during the NIMS allocation process. Government and industry studies have also considered sector energy trends, such as the Dairy Roadmap and the IEEA guides to the dairy, animal feed, confectionary stoving and industrial baking sub-sectors. No significant data sources were identified covering product substitution trends.

Abatement potential

The data coverage on abatement potential in the food manufacture sector is moderate. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however. Beyond this the sector has been subject to several government and industry studies on abatement potential. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. Academic and trade literature quantifies sector specific technology abatement opportunities, such as Pereira and Vincente (2010). Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C11 Manufacture of beverages

Research question	Factor	Quality	Source
Energy trends	Total consumption	High	IEEA malting and brewing sector guides, National inventory, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	EUETS annual submission, NIMS allocation process, CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	CCA sector negotiations, ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	There are no significant non-energy process emissions
	Energy efficiency data for sector	Medium	CCA sector negotiations, CCA sector submissions, Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	Medium	IEEA sector guides, ENUSIM
	Capital costs	Medium	IEEA sector guides, CCA sector negotiations, ECA, ENUSIM, MARKAL
	Operational costs	Medium	MARKAL, ENUSIM

Research question	Factor	Quality	Source
	Expected life time of plant	Medium	CCA sector negotiations, ECA, MARKAL, ENUSIM
	Technology maturity	Low	IEEA Brewing sector guide
	Penetration / uptake rate	Medium	CCA sector negotiations, ENUSIM, ECA
	Age profile of current plant	Medium	MARKAL, ENUSIM
	Cost effective abatement performance	Medium	CCA sector negotiations, AEA (2010), 2050 pathways analysis, POLES, ECA, MARKAL
	Technical abatement performance	Medium	IEEA sector guides, AEA (2010), CCA sector negotiations, MARKAL, ENUSIM, Pereira and Vincente (2010)
Barriers	Sector specific barriers	Low	IEEA Brewing sector guide, 2050 pathways analysis
	Sector specific enablers	Low	IEEA sector guides, 2050 pathways analysis, Sandberg and Söderström (2003)
	Technology specific barriers	Low	IEEA sector guides, CCA sector negotiations, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the beverage manufacture sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. Government and industry studies have also considered sector energy trends, such as the IEEA guides to the maltings and brewing sub-sectors. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the beverage manufacture sector is moderate. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. Beyond this the sector has been subject to several

government and industry studies on abatement potential. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. Academic and trade literature quantifies sector specific technology abatement opportunities. Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised..

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C12 Manufacture of tobacco products

Research question	Factor	Quality	Source
Energy trends	Total consumption	Low	National inventory, MARKAL, POLES, ECUK
	Core process energy consumption	Low	EUETS annual submission, NIMS allocation process, ECUK, MARKAL
	Non-core energy consumption	Low	ECUK, MARKAL
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Low	Hammond and Norman (2011), ECUK
	Heat generation (Low quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Low	ENUSIM
	Capital costs	Low	ECA, MARKAL, ENUSIM
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	ECA, MARKAL, ENUSIM
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Low	ECA, ENUSIM

Research question	Factor	Quality	Source
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Low	MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	ECA

Energy trends

The data coverage on energy consumption trends within the tobacco sector is very low. Information is available from audited primary datasets but only at an aggregate level. CCA sector coverage is likely to be negligible. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the tobacco sector is very low. The industry is represented as part of an aggregate in a number of the energy models, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

C13 Manufacture of textiles

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	National inventory, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	EUETS annual submission, NIMS allocation process, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Medium	CCA sector submissions, Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Low	ENUSIM
	Capital costs	Medium	ENUSIM, CCA sector negotiations, ECA, MARKAL
	Operational costs	Low	MARKAL
	Expected life time of plant	Medium	ECA, MARKAL, ENUSIM

Research question	Factor	Quality	Source
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Low	ENUSIM, ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Low	MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the textiles sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the textiles sector is low. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

C14 Manufacture of wearing apparel

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	National inventory, MARKAL, ENUSIM, POLES, ECUK
	Core process energy consumption	Medium	ENUSIM, EUETS annual submission, NIMS allocation process, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector (for site data)	Low	CCA sector submissions, Hammond and Norman (2011), ECUK
	Heat generation (Low quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	None	No data source identified
	Capital costs	Low	ECA, MARKAL, ENUSIM
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	CCA sector negotiations, ECA, MARKAL
	Technology maturity	None	No data source identified

Research question	Factor	Quality	Source
	Penetration / uptake rate	Low	ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Low	MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	ECA

Energy trends

The data coverage on energy consumption trends within the wearing apparel sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. This represents good sector coverage. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the wearing apparel sector is low. The industry is represented as part of an aggregate in a number of the energy models, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

C15 Manufacture of leather and related products

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	National inventory, MARKAL, ENUSIM, POLES, ECUK
	Core process energy consumption	Medium	ENUSIM, EUETS annual submission, NIMS allocation process, CCA sector submissions, ENUSIM, ECUK, MARKAL
	Non-core energy consumption	Medium	ENUSIM, ECUK, MARKAL
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Medium	CCA sector submissions, ENUSIM, G Hammond and J Norman (2011), ECUK, ENUSIM
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, NIMS allocator
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Low	ENUSIM
	Capital costs	Low	ENUSIM, ECA, MARKAL
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Medium	ENUSIM, ECA, MARKAL
	Technology maturity	None	No data source identified

Research question	Factor	Quality	Source
	Penetration / uptake rate	Low	ENUSIM, ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, ENUSIM, POLES, ECA, MARKAL
	Technical abatement performance	Low	ENUSIM, MARKAL
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the leather sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. This represents good sector coverage. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the leather sector is low. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

C16 Manufacture of wood and of products of wood and cork except furniture manufacture of articles of straw and plaiting materials

Research question	Factor	Quality	Source
Energy trends	Total consumption	Low	National inventory, MARKAL, POLES, ECUK
	Core process energy consumption	Low	EUETS annual submission, NIMS allocation process, CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Low	CCA sector negotiations, ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Low	CCA sector negotiations, CCA sector submissions, Hammond and Norman (2011), ECUK
	Heat generation (Low quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	None	No data source identified
	Capital costs	Low	CCA sector negotiations, ECA, MARKAL, ENUSIM
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	CCA sector negotiations, ECA, MARKAL

Research question	Factor	Quality	Source
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Low	CCA sector negotiations, ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	CCA sector negotiations, 2050 pathways analysis, POLES, ECA, MARKAL
	Technical abatement performance	Low	CCA sector negotiations, MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	CCA sector negotiations, ECA

Energy trends

The data coverage on energy consumption trends within the wood products sector is low. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. This represents low sector coverage (estimated to be in the region of 30%). It may be the case that EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the wood products sector is low. The industry is represented as part of an aggregate in a number of the energy models, where the source data is typically based on standard assumptions relating to industrial activity. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C17 Manufacture of paper and paper products

Research question	Factor	Quality	Source
Energy trends	Total consumption	High	Paper Roadmap (CEPI), IEEA Paper sector guide, EUETS annual submission, NIMS allocation process,, National inventory, , Centre for Low Carbon Futures (2011), Horizon 2050 (Climate Action Europe Network), ENUSIM, MARKAL, POLES, ECUK, Hammond and Norman (2012)
	Core process energy consumption	Medium	CCA sector negotiations, CCA sector submissions, , ECUK, MARKAL, ENUSIM, Szabó *et al.* (2009)
	Non-core energy consumption	Medium	CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-energy process emissions	High	National inventory
	Energy efficiency data for sector	High	CCA sector negotiations, CCA sector submissions, G Hammond *et al*. (2009), G Hammond and J Norman (2011), ENUSIM, ECUK, Szabó *et al.* (2009)
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Medium	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Medium	EUETS annual submission, NIMS allocation process,, Hammond *et al*. (2009)
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, Horizon 2050 (Climate Action Europe Network), EUETS annual submission, NIMS allocation

Research question	Factor	Quality	Source
			process,, Szabó *et al.* (2009)
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	Medium	IEEA Paper sector guide, ENUSIM
	Capital costs	High	Paper Roadmap (CEPI), IEEA Paper sector guide, CCA sector negotiations, ENUSIM, ECA, MARKAL, Horizon 2050 (Climate Action Europe Network), Centre for Low Carbon Futures (2011), Kramer *et al.* (2009), Hayakawa and Suzuoki (1999)
	Operational costs	Medium	MARKAL, Horizon 2050 (Climate Action Europe Network), ENUSIM
	Expected life time of plant	Medium	IEEA Paper sector guide, CCA sector negotiations, ECA, MARKAL, ENUSIM
	Technology maturity	Low	IEEA Paper sector guide, Horizon 2050 (Climate Action Europe Network)
	Penetration / uptake rate	Medium	IEEA Paper sector guide, CCA sector negotiations, ENUSIM, ECA,
	Age profile of current plant	Medium	MARKAL, ENUSIM
	Cost effective abatement performance	High	AEA (2010), CCA sector negotiations, 2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM, Centre for Low Carbon Futures (2011), Ruohonen and Ahtila (2010)
	Technical abatement performance	High	Paper Roadmap (CEPI), IEEA Paper sector guide, AEA (2010), CCA sector negotiations, MARKAL, SERPEC-CC (2009), ENUSIM, Horizon 2050 (Climate Action Europe Network), Hammond and Norman (2012), McKenna and Norman (2010), Kramer *et al.* (2009), Ruohonen *et al*. (2010), Szabó *et al.* (2009)

Research question	Factor	Quality	Source
Barriers	Sector specific barriers	Low	IEEA Paper sector guide, 2050 pathways analysis, Centre for Low Carbon Futures (2011)
	Sector specific enablers	Low	Paper Roadmap (CEPI), IEEA Paper sector guide, 2050 pathways analysis, Centre for Low Carbon Futures (2011)
	Technology specific barriers	Medium	IEEA Paper sector guide, Horizon 2050 (Climate Action Europe Network), CCA sector negotiations, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the paper sector is high. Information is available from audited primary datasets at a high resolution. Consumption data can be sourced from CCA and EU ETS submissions. Data on heat generation and consumption can also be derived from EU ETS annual data and was also submitted, as one off exercise, during the NIMS allocation process. Government and industry studies have also considered sector energy trends, such as the Paper Roadmap. Non-energy process emissions are recorded in the National inventory. No significant data sources were identified covering product substitution trends. We would expect there to be additional studies. This may be due to an error in our search terms.

Abatement potential

The data coverage on abatement potential in the paper sector is moderate. The industry is explicitly represented in the ENUSIM & MARKAL models, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however. Beyond this the sector has been subject to several government and industry studies on abatement potential. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. Academic and trade literature quantifies sector specific technology abatement opportunities. Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C18 Printing and reproduction of recorded media

Research question	Factor	Quality	Source
Energy trends	Total consumption	Low	National inventory, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Low	EUETS annual submission, NIMS allocation process, CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Low	CCA sector negotiations, ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Low	CCA sector negotiations, CCA sector submissions, Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	Low	ENUSIM
	Capital costs	Medium	ENUSIM, CCA sector negotiations, ECA, MARKAL
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	CCA sector negotiations, ECA, MARKAL, ENUSIM
	Technology maturity	None	No data source identified

Research question	Factor	Quality	Source
	Penetration / uptake rate	Low	CCA sector negotiations, ENUSIM, ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	CCA sector negotiations, 2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Low	CCA sector negotiations, MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	CCA sector negotiations, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the printing sector is low. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. Sector CCA coverage is ~60%. It may be the case that EUETS data is available on large combustion processes. This could provide information on heat usage and generation. Sector EUETS coverage is ~50%. No significant further data sources could be identified on site efficiency, heat generation/use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the printing sector is low. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C19 Manufacture of coke and refined petroleum products

Research question	Factor	Quality	Source
Energy trends	Total consumption	High	Concawe (2013), Refineries Roadmap (Europia), UKPIA (2012), EUETS annual submission, NIMS allocation process,, National inventory, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	EUETS annual submission, NIMS allocation process, UKPIA (2012), ECUK, MARKAL, Eldridge *et al*. (2005)
	Non-core energy consumption	Medium	EUETS annual submission, NIMS allocation process,, ECUK, MARKAL
	Non-energy process emissions	High	National inventory
	Energy efficiency data for sector	High	Concawe (2013), Refineries Roadmap (Europia), UKPIA (2012), EUETS annual submission, NIMS allocation process, G Hammond and J Norman (2011), ECUK
	Heat generation (Low quality)	High	MARKAL, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	High	MARKAL, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	High	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	High	EUETS annual submission, NIMS allocation process
	Activity (market)	High	UKPIA (2012), PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	Medium	Extensive literature on role of biofuels
Abatement potential	Sector applicability	None	No data source identified

Research question	Factor	Quality	Source
	Capital costs	Medium	CCA sector negotiations, ECA, MARKAL, Kuramochi *et al*. (2011), Jegla *et al*. (2003), Castelo Branco *et al*. (2011), Heeres *et al*. (2004), Fennell *et al*. (2012)
	Operational costs	Medium	MARKAL
	Expected life time of plant	Medium	MARKAL
	Technology maturity	Medium	Heeres *et al*. (2004), Fennell *et al*. (2012)
	Penetration / uptake rate	Low	ECA, Heeres *et al*. (2004),
	Age profile of current plant	Low	MARKAL
	Cost effective abatement performance	Medium	AEA (2010), 2050 pathways analysis, POLES, ECA, Worrell and Gatlitsky (2008)
	Technical abatement performance	Medium	AEA (2010), MARKAL, SERPEC-CC (2009), Kuramochi *et al*. (2011), Ashaibani and Mujtaba (2007), Gadalla *et al*. (2003), Johansson *et al*. (2012), Hayakawa and Suzuoki (1999), Eldridge *et al*. (2005)
Barriers	Sector specific barriers	Low	Johansson *et al*. (2012), 2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Medium	ECA, Jegla *et al*. (2003), Eldridge *et al*. (2005)

Energy trends

The data coverage on energy consumption trends within the refineries sector is high. Information is available from audited primary datasets at a high resolution. Consumption data is available through the EU ETS. Data on heat generation and consumption can also be derived from EU ETS annual data and was also submitted, as one off exercise, during the NIMS allocation process. Government and industry studies have also considered sector energy trends, such as Concawe (2013) and the Refineries Roadmap. Non-energy process emissions are recorded in the National inventory. No

significant data sources were identified covering product substitution trends. We would expect there to be additional studies. This may be due to an error in our search terms.

Abatement potential

The data coverage on abatement potential in the refineries sector is moderate. The industry is covered in the major energy models but only as an aggregate and it is excluded altogether from ENUSIM. Beyond this the sector has been subject to several government and industry studies on abatement potential. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. Academic and trade literature quantifies sector specific technology abatement opportunities. This includes Ashaibani and Mujtaba (2007), Gadalla *et al*. (2003) and

Johansson *et al*. (2012). Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C20 Manufacture of chemicals and chemical products

Research question	Factor	Quality	Source
Energy trends	Total consumption	High	CCA sector submissions, National inventory, EUETS annual submission, NIMS allocation process, TINA, Chemicals roadmap (CEFIC & ECOFYS), ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process, Eldridge *et al*. (2005)
	Non-core energy consumption	Medium	CCA sector negotiations, CCA sector submissions, EUETS annual submission, NIMS allocation process, ECUK, MARKAL, ENUSIM
	Non-energy process emissions	High	National inventory
	Energy efficiency data for sector (Site consumption data	High	CCA sector negotiations, CCA sector submissions, EUETS annual submission, NIMS allocation process, G Hammond *et al*. (2009), G Hammond and J Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	High	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	High	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	High	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	High	EUETS annual submission, NIMS allocation process,, Hammond *et al*. (2009)
	Activity (market)	High	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process

Research question	Factor	Quality	Source
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	Low	TINA, ENUSIM
	Capital costs	High	CCA sector negotiations, TINA, ECA, MARKAL, ENUSIM, Centre for Low Carbon Futures (2011)
	Operational costs	Medium	MARKAL, ENUSIM
	Expected life time of plant	Medium	CCA sector negotiations, ECA, MARKAL, ENUSIM
	Technology maturity	Low	TINA
	Penetration / uptake rate	Medium	CCA sector negotiations, MARKAL, ENUSIM, ECA, TINA
	Age profile of current plant	Medium	TINA, MARKAL, ENUSIM
	Cost effective abatement performance	Medium	AEA (2010), CCA sector negotiations, 2050 pathways analysis, ECA, ENUSIM, MARKAL, Centre for Low Carbon Futures (2011)
	Technical abatement performance	Medium	Chemicals roadmap (CEFIC & ECOFYS), AEA (2010), CCA sector negotiations, Gadalla *et al.* (2005), TINA, MARKAL, SERPEC-CC (2009), ENUSIM, Saygin *et al*. (2009), Hammond and Norman (2012), McKenna and Norman (2010), Eldridge *et al*. (2005)
Barriers	Sector specific barriers	Low	Chemicals roadmap (CEFIC & ECOFYS), TINA, 2050 pathways analysis, Centre for Low Carbon Futures (2011)
	Sector specific enablers	Low	TINA, 2050 pathways analysis, Saygin *et al*. (2009)
	Technology specific barriers	Medium	CCA sector negotiations, ENUSIM, ECA, TINA, Eldridge *et al*. (2005)

Energy trends

The data coverage on energy consumption trends within the chemicals sector is high. Information is available from audited primary datasets at a high resolution. Consumption data can be sourced from CCA and EU ETS submissions. Data on heat generation and consumption can be derived from EU ETS annual submission data and was also submitted, as a one off exercise, during the NIMS allocation process. Government and industry studies have also considered sector energy trends, such as the Chemicals Roadmap (CEFIC & ECOFYS). Non-energy process emissions are recorded in the National inventory. No significant data sources were identified covering product substitution trends. We would expect there to be additional studies. This may be due to an error in our search terms.

Abatement potential

The data coverage on abatement potential in the chemicals sector is moderate. The industry is explicitly represented in a number of the energy models, where the source data is typically based on industry consultation exercises, expert reviews and available literature. Beyond this the sector has been subject to several government and industry studies on abatement potential. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. Academic and trade literature quantifies sector specific technology abatement opportunities. This includes Gadalla *et al.* (2005) and Saygin *et al*. (2009). Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations

Research question	Factor	Quality	Source
Energy trends	Total consumption	Low	National inventory, MARKAL, POLES, ECUK
	Core process energy consumption	Low	EUETS annual submission, NIMS allocation process, ECUK, MARKAL
	Non-core energy consumption	Low	ECUK, MARKAL
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Low	Hammond and Norman (2011), ECUK
	Heat generation (Low quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Low	ENUSIM
	Capital costs	Low	ECA, MARKAL, ENUSIM
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	ECA, MARKAL, ENUSIM
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Low	ECA, ENUSIM

Research question	Factor	Quality	Source
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Low	MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	ECA

Energy trends

The data coverage on energy consumption trends within the pharmaceutical sector is very low. Information is available from audited primary datasets but only at an aggregate level. CCA sector coverage is likely to be negligible. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the pharmaceutical sector is very low. The industry is represented as part of an aggregate in a number of the energy models, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

C22 Manufacture of rubber and plastic products

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	National inventory, AEA & ECOFYS, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	EUETS annual submission, NIMS allocations, sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	ECUK, MARKAL, ENUSIM
	Non-energy process emissions	Medium	National inventory
	Energy efficiency data for sector	Medium	CCA sector submissions, Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Medium	IEEA Plastic blow moulding sector guide, ENUSIM
	Capital costs	Medium	IEEA Plastic blow moulding sector guide, ENUSIM, CCA sector negotiations, ECA, MARKAL
	Operational costs	Medium	MARKAL, ENUSIM
	Expected life time of plant	Medium	ECA, MARKAL, ENUSIM
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Medium	ENUSIM, ECA

Research question	Factor	Quality	Source
	Age profile of current plant	Medium	MARKAL, ENUSIM
	Cost effective abatement performance	Medium	2050 pathways analysis, POLES, ECA, MARKAL
	Technical abatement performance	Medium	IEEA Plastic blow moulding sector guide, MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	IEEA Plastic blow moulding sector guide, 2050 pathways analysis
	Technology specific barriers	Low	IEEA Plastic blow moulding sector guide, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the rubber and plastics manufacture sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. The IEEA guide to the plastic blow moulding sub-sector provides primary data on energy consumption trends, but with low sector coverage. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the rubber and plastics manufacture sector is moderate. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. The IEEA guide provides data on sector applicability, capital costs and abatement potential for technologies, but with low sector coverage. Beyond this there are limited sector specific insights from government and industry. Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

C23 Manufacture of other non-metallic mineral products

The non-metallic minerals sector covers cement, ceramics, glass, gypsum and lime sub-sectors.

Research question	Factor	Quality	Source
Energy trends	Total consumption	High	Cement Roadmap (IEA), Cement Roadmap (MPA), Ceramic Roadmap (Cerame-Unie), IEEA Brick and Asphalt sector guides, Horizon 2050 (Climate Action Europe Network), AEA & ECOFYS (2008), ECUK, POLES, MARKAL, ENUSIM, Centre for Low Carbon Futures (2011), National inventory, EUETS annual submission, NIMS allocation process, TINA, Hammond and Norman (2012),
	Core process energy consumption	Medium	CCA sector negotiations, CCA sector submissions, EUETS annual submission, NIMS allocation process, MARKAL, ENUSIM, ECUK
	Non-core energy consumption	Medium	CCA sector negotiations, MARKAL, ENUSIM ECUK
	Non-energy process emissions	High	National inventory
	Energy efficiency data for sector (Site consumption data)	High	Cement Roadmap (IEA), IEEA Asphalt sector guide, , EUETS annual submission, NIMS allocation process, ENUSIM, ECUK, G Hammond *et al*. (2009), G Hammond and J Norman (2011),
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, , EUETS annual submission, NIMS allocation process,
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, , EUETS annual submission, NIMS allocation process,
	Heat usage (Low quality)	Medium	EUETS annual submission, NIMS allocation process,
	Heat usage (High quality)	Medium	EUETS annual submission, NIMS allocation process,, G Hammond *et al*. (2009)
	Activity (market)	High	IEEA Bricks sector guide, CCA sector submissions, PRODCOM, POLES, Horizon 2050 (Climate Action Europe Network), 2050 pathway analysis, , EUETS annual submission, NIMS allocation process,

	Product substitution	Low	Horizon 2050 (Climate Action Europe Network), CCA sector negotiations, TINA, Gartner (2004), Schoon *et al*. (2004), Chen *et al*. (2010), Schneider *et al*. (2011)
Abatement potential	Sector applicability	Medium	TINA, IEEA Bricks and Asphalt sector guides, ENUSIM
	Capital costs	Medium	CCA sector negotiations, IEEA Brick and Asphalt sector guides, TINA, Horizon 2050 (Climate Action Europe Network), ECRA & CSI (2009), European Commission IPTS (2013), ECA, MARKAL, ENUSIM, Centre for Low Carbon Futures (2011), T Kuramochi *et al*. (2011), Schneider *et al*. (2011), Fennell *et al*. (2012)
	Operational costs	Low	MARKAL, ENUSIM, ECRA & CSI (2009), European Commission IPTS (2013)
	Expected life time of plant	Medium	CCA sector negotiations, ECA, MARKAL, ENUSIM
	Technology maturity	Low	Cement Roadmap (IEA), IEEA Brick and Asphalt sector guides, TINA
	Penetration / uptake rate	Medium	Ceramic Roadmap (Cerame-Unie), CCA sector negotiations, ENUSIM, MARKAL, ECA, TINA, European Commission IPTS (2013)
	Age profile of current plant	Medium	TINA, MARKAL
	Cost effective abatement performance	High	AEA (2010), CCA sector negotiations, POLES, 2050 pathways analysis, ECA, ENUSIM, MARKAL, Centre for Low Carbon Futures (2011)
	Technical abatement performance	High	Cement Roadmap (MPA), Ceramic Roadmap (Cerame-Unie), IEEA Brick and Asphalt sector guides, AEA (2010), CCA sector negotiations, TINA, SERPEC-CC (2009), ENUSIM, MARKAL, European Commission IPTS (2013), ECRA & CSI (2009), Pardo and Moya (2013), Agrafiotis and Tsoutos (2001), Kuramochi *et al*. (2011), Worrell (2008), Gartner (2004), Hammond and Norman (2012), McKenna and Norman (2010), Schoon *et al*. (2004), Kabir *et al*. (2010)

Barriers	Sector specific barriers	Low	TINA, 2050 pathways analysis, Centre for Low Carbon Futures (2011)
	Sector specific enablers	Medium	2050 pathways analysis, Centre for Low Carbon Futures (2011)
	Technology specific barriers	Medium	Cement Roadmap (IEA), IEEA Brick and Asphalt sector guides, ECRA & CSI (2009), CCA sector negotiations, ENUSIM, ECA, TINA

Energy trends

The data coverage on energy consumption trends within the non-metallic minerals sector is high. Information is available from audited primary datasets at a high resolution. Consumption data can be sourced from CCA and EU ETS submissions. Data on heat generation and consumption can be derived from EU ETS annual submission data and was also submitted, as one off exercise, during the NIMS allocation process. Government and industry studies have also considered sector energy trends, such as the Cement and Ceramic Roadmaps. Non-energy process emissions are recorded in the National inventory. Product substitution opportunities are documented extensively in government studies and academic literature.

Abatement potential

The data coverage on abatement potential in the non-metallic minerals sector is moderate to high. The industry is explicitly represented in a number of the energy models, where the source data is typically based on industry consultation exercises, expert reviews and available literature. Beyond this the sector has been subject to several government and industry studies on abatement potential. This includes the Roadmaps and IEEA guides for the asphalt and brick sub-sectors. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. Academic and trade literature quantifies sector specific technology abatement opportunities. This includes Worrell (2008), Gartner (2004) and Schoon *et al*. (2004).

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C24 Manufacture of basic metals

Research question	Factor	Quality	Source
Energy trends	Total consumption	High	Steel Roadmap (EUROFER), Horizon 2050 (Climate Action Europe Network), EUETS annual submission, NIMS allocation process, CCA, ECUK, POLES, MARKAL, ENUSIM, National inventory, NIMS allocator, TINA, Hammond and Norman (2012) Yih-Liang Chan *et al*. (2010)
	Core process energy consumption	Medium	CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	CCA sector negotiations, ECUK
	Non-energy process emissions	High	National inventory
	Energy efficiency data for sector (Site consumption data)	High	Steel Roadmap (EUROFER), UCLOS (2009), CCA sector negotiations, CCA sector submissions, ENUSIM
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Medium	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Medium	EUETS annual submission, NIMS allocation process, Hammond *et al*. (2009)
	Activity (market)	High	Horizon 2050 (Climate Action Europe Network), CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process, Moya and Pardo (2013)
	Product substitution	Low	CCA sector negotiations, Johansson

Research question	Factor	Quality	Source
			and Söderström (2011)
Abatement potential	Sector applicability	Low	TINA, ENUSIM
	Capital costs	Medium	CCA sector negotiations, ECA, ENUSIM, MARKAL, Horizon 2050 (Climate Action Europe Network), Centre for Low Carbon Futures (2011),Kuramochi *et al*. (2011), Moya and Pardo (2013), Fennell *et al*. (2012)
	Operational costs	Medium	ENUSIM, MARKAL, Horizon 2050 (Climate Action Europe Network),
	Expected life time of plant	Medium	CCA sector negotiations, ECA, MARKAL, ENUSIM,
	Technology maturity	Low	Horizon 2050 (Climate Action Europe Network), TINA, Moya and Pardo (2013)
	Penetration / uptake rate	Medium	CCA sector negotiations, MARKAL, ENUSIM, ECA, TINA
	Age profile of current plant	Medium	TINA, MARKAL
	Cost effective abatement performance	Medium	AEA (2010), Steel Roadmap (EUROFER), CCA sector negotiations, 2050 pathways analysis, ECA, MARKAL, ENUSIM, Centre for Low Carbon Futures (2011), Moya and Pardo (2013), Kaempf (2007)
	Technical abatement performance	Medium	AEA (2010), CCA sector negotiations, TINA, Horizon 2050 (Climate Action Europe Network), SERPEC-CC (2009), ENUSIM, MARKAL, Kuramochi *et al*. (2011), Hammond and Norman (2012), McKenna and Norman (2010), Moya and Pardo (2013), Pardo and Moya (2013), Yih-Liang Chan *et al*. (2010), Johansson and Söderström (2011)
Barriers	Sector specific barriers	Low	TINA, 2050 pathways analysis

Research question	Factor	Quality	Source
	Sector specific enablers	Low	Steel Roadmap (EUROFER), TINA, 2050 pathways analysis
	Technology specific barriers	Low	Horizon 2050 (Climate Action Europe Network), Johansson and Söderström (2011), CCA sector negotiations, ENUSIM, ECA, TINA

Energy trends

The data coverage on energy consumption trends within the basic metals sector is high. Information is available from audited primary datasets at a high resolution. Consumption data can be sourced from CCA and EU ETS submissions. Data on heat generation and consumption can be derived from EU ETS annual submission data and was also submitted, as one off exercise, during the NIMS allocation process. Government and industry studies have also considered sector energy trends, such as the Steel Roadmap. Non-energy process emissions are recorded in the National inventory. Product substitution opportunities are documented extensively in government studies and academic literature, including Johansson and Söderström (2011).

Abatement potential

The data coverage on abatement potential in the basic metals sector is moderate. The industry is explicitly represented in a number of the energy models, where the source data is typically based on industry consultation exercises, expert reviews and available literature. Beyond this the sector has been subject to several government studies on abatement potential. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. Academic and trade literature quantifies sector specific technology abatement opportunities. This includes Moya and Pardo (2013), Pardo and Moya (2013) and Yih-Liang Chan *et al*. (2010). Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C25 Manufacture of fabricated metal products except machinery and equipment

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	IEEA Metalforming sector guide, National inventory, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	EUETS annual submission, NIMS allocation process, CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	CCA sector negotiations, ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Medium	CCA sector negotiations, CCA sector submissions, Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	Medium	IEEA Metalforming sector guide, ENUSIM
	Capital costs	Medium	IEEA Metalforming sector guide, ENUSIM, CCA sector negotiations, ECA, MARKAL

Research question	Factor	Quality	Source
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Medium	CCA sector negotiations, ECA, MARKAL, ENUSIM
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Low	CCA sector negotiations, ENUSIM, ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	CCA sector negotiations, 2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Medium	IEEA Metalforming sector guide, CCA sector negotiations, MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	IEEA Metalforming sector guide, 2050 pathways analysis
	Sector specific enablers	Low	IEEA Metalforming sector guide, 2050 pathways analysis
	Technology specific barriers	Low	CCA sector negotiations, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the fabricated metal products sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. This represents low sector coverage, however (estimated in the region of 20%). It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. Coverage in this regard is, again, low (estimated in the region of 30%). The IEEA guide to the metalforming sector provides primary data on energy consumption trends with high sector coverage. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the fabricated metal products sector is moderate. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard

assumptions relating to industrial activity. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. The IEEA guide provides data on sector applicability, capital costs and abatement potential for technologies. Beyond this there are limited sector specific insights from government and industry. Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C26 Manufacture of computer, electronic and optical products

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	IEEA Microelectronics sector guide, National inventory, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Low	IEEA Microelectronics sector guide, EUETS annual submission, NIMS allocation process, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Low	ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Low	CCA sector submissions, Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Medium	IEEA Microelectronics sector guide, ENUSIM
	Capital costs	Medium	IEEA Microelectronics sector guide, ENUSIM, ECA, MARKAL
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	ECA, MARKAL, ENUSIM
	Technology maturity	Medium	IEEA Microelectronics sector guide

Research question	Factor	Quality	Source
	Penetration / uptake rate	Medium	IEEA Microelectronics sector guide, ENUSIM, ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Medium	IEEA Microelectronics sector guide, MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	IEEA Microelectronics sector guide, 2050 pathways analysis
	Sector specific enablers	Low	IEEA Microelectronics sector guide, 2050 pathways analysis
	Technology specific barriers	Low	IEEA Microelectronics sector guide, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the fabricated metal products sector is low. Information is available from audited primary datasets but only at an aggregate level. The 2003 SIC category, 'Manufacture of Radio, Television and Communication Equipment and Apparatus' has CCA coverage of ca. 70%. This only covers a small portion of the electronic products sector. The remainder of the sector has negligible CCA and EU ETS coverage. The IEEA guide to the microelectronics sector provides primary data on energy consumption trends with moderate sector coverage. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the fabricated metal products sector is low. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. The IEEA guide provides data on sector applicability, capital costs and abatement potential for technologies. Beyond this there are limited sector specific insights from government and industry. Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in both government and industry publications, they are often only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

C27 Manufacture of electrical equipment

Research question	Factor	Quality	Source
Energy trends	Total consumption	Low	National inventory, MARKAL, POLES, ECUK
	Core process energy consumption	Low	CCA sector negotiations, CCA sector submissions, EUETS annual submission, NIMS allocation process , ECUK, MARKAL
	Non-core energy consumption	Low	CCA sector negotiations, ECUK, MARKAL
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Low	CCA sector negotiations, CCA sector submissions, Hammond and Norman (2011), ECUK
	Heat generation (Low quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	None	No data source identified
	Capital costs	Low	CCA sector negotiations, ECA, MARKAL, ENUSIM
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	CCA sector negotiations, ECA, MARKAL, ENUSIM

Research question	Factor	Quality	Source
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Low	CCA sector negotiations , ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	CCA sector negotiations, 2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Low	CCA sector negotiations, MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	CCA sector negotiations, ECA

Energy trends

The data coverage on energy consumption trends within the wood products sector is low. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. However, sector coverage is insignificant (estimated to be in the region of 5%). It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the electrical equipment sector is low. The industry is represented as part of an aggregate in a number of the energy models, where the source data is typically based on standard assumptions relating to industrial activity. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C28 Manufacture of machinery and equipment n e c

Research question	Factor	Quality	Source
Energy trends	Total consumption	Low	AEA & ECOFYS, National inventory, MARKAL, POLES, ECUK
	Core process energy consumption	Low	CCA sector submissions, EUETS annual submission, NIMS allocation process ECUK, MARKAL
	Non-core energy consumption	Low	ECUK, MARKAL
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Low	CCA sector submissions, Hammond and Norman (2011), ECUK
	Heat generation (Low quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	None	No data source identified
	Capital costs	Low	MARKAL, ENUSIM
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	CCA sector negotiations, MARKAL, ENUSIM
	Technology maturity	None	No data source identified

Research question	Factor	Quality	Source
	Penetration / uptake rate	Low	CCA sector negotiation
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	CCA sector negotiations, 2050 pathways analysis, POLES
	Technical abatement performance	Low	MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	ECA

Energy trends

The data coverage on energy consumption trends within the machinery manufacture sector is low. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. This represents low sector coverage (estimated to be in the region of 25%). It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the machinery manufacture sector is low. The industry is represented as part of an aggregate in a number of the energy models, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C29 Manufacture of motor vehicles, trailers and semi-trailers

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	Automotive Sustainability Report (2013) , National inventory, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	EUETS annual submission, NIMS allocation process, CCA sector negotiations, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	CCA sector negotiations, ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Medium	CCA sector negotiations, CCA sector submissions, Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	Automotive Sustainability Report (2013), CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	Low	CCA sector negotiations
Abatement potential	Sector applicability	Medium	ENUSIM
	Capital costs	Medium	ENUSIM, CCA sector negotiations, ECA, MARKAL
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Medium	CCA sector negotiations, ECA, MARKAL, ENUSIM
	Technology maturity	None	No data source identified

Research question	Factor	Quality	Source
	Penetration / uptake rate	Medium	CCA sector negotiations, ENUSIM, ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Medium	CCA sector negotiations, 2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Medium	CCA sector negotiations, MARKAL, ENUSIM, G. Hammond and J. Norman (2012), R. McKenna and J. Norman (2010)
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	CCA sector negotiations, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the automotive sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. The Automotive Roadmap documents sector energy trends. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the automotive sector is moderate. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. The recent CCA negotiation process provides an insight into current perceptions of technology potential by type. Beyond this there are limited sector specific insights from government and industry. Weaker datasets include sector applicability of technologies and uptake rates by technology, where findings are generally only qualitatively appraised.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C30 Manufacture of other transport equipment

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	National inventory, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	EUETS annual submission, NIMS allocation process, CCA sector submissions, ECUK, MARKAL, ENUSIM
	Non-core energy consumption	Medium	ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Medium	CCA sector submissions, Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	CCA sector submissions, PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Low	ENUSIM
	Capital costs	Medium	ENUSIM, ECA, MARKAL
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Medium	ECA, MARKAL, ENUSIM

Research question	Factor	Quality	Source
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Low	ENUSIM, ECA
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Low	MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	CCA sector negotiations, ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the other transport manufacture sector is moderate. Information is available from audited primary datasets but only at an aggregate level. Consumption data, for instance, can be sourced from CCA submissions. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the other transport manufacture sector is low. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exceptions are ENUSIM, where data on hidden costs affects realistic abatement potential, and CCA negotiations, where the impact of technology specific barriers as an aggregate is quantified.

C31 Manufacture of furniture

Research question	Factor	Quality	Source
Energy trends	Total consumption	Medium	National inventory, ENUSIM, MARKAL, POLES, ECUK
	Core process energy consumption	Medium	ECUK, EUETS annual submission, NIMS allocation process, MARKAL, ENUSIM
	Non-core energy consumption	Low	ECUK, MARKAL, ENUSIM
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Medium	Hammond and Norman (2011), ENUSIM, ECUK
	Heat generation (Low quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Medium	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Low	ENUSIM
	Capital costs	Low	ENUSIM, ECA, MARKAL
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Medium	ENUSIM, ECA, MARKAL
	Technology maturity	None	No data source identified
	Penetration / uptake	Low	ENUSIM, ECA

Research question	Factor	Quality	Source
	rate		
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, ENUSIM, POLES, ECA, MARKAL
	Technical abatement performance	Low	ENUSIM, MARKAL
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	ENUSIM, ECA

Energy trends

The data coverage on energy consumption trends within the furniture manufacture sector is very low. Information is available from audited primary datasets but only at an aggregate level. CCA sector coverage is likely to be negligible. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the furniture manufacture sector is low. The industry is explicitly represented in the ENUSIM model, where the source data is based on industry consultation exercises, expert reviews and available literature. Sector coverage in the other major energy models is aggregated, however, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

C32 Other manufacturing

The other manufacturing sector consists of the manufacture of jewellery, musical instruments, sports goods, games and toys, medical and dental instruments and any other manufacturing not covered elsewhere.

Research question	Factor	Quality	Source
Energy trends	Total consumption	Low	National inventory, MARKAL, POLES, ECUK
	Core process energy consumption	Low	EUETS annual submission, NIMS allocation process, ECUK, MARKAL
	Non-core energy consumption	Low	ECUK, MARKAL
	Non-energy process emissions	N/A	No significant non-energy process emissions
	Energy efficiency data for sector	Low	Hammond and Norman (2011), ECUK
	Heat generation (Low quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat generation (High quality)	Low	MARKAL, ENUSIM, EUETS annual submission, NIMS allocation process
	Heat usage (Low quality)	Low	EUETS annual submission, NIMS allocation process
	Heat usage (High quality)	Low	EUETS annual submission, NIMS allocation process
	Activity (market)	Medium	PRODCOM, POLES, 2050 pathway analysis, EUETS annual submission, NIMS allocation process
	Product substitution	None	No data source identified
Abatement potential	Sector applicability	Low	ENUSIM
	Capital costs	Low	ECA, MARKAL, ENUSIM
	Operational costs	Low	MARKAL, ENUSIM
	Expected life time of plant	Low	ECA, MARKAL, ENUSIM

Research question	Factor	Quality	Source
	Technology maturity	None	No data source identified
	Penetration / uptake rate	Low	ECA, ENUSIM
	Age profile of current plant	Low	MARKAL, ENUSIM
	Cost effective abatement performance	Low	2050 pathways analysis, POLES, ECA, MARKAL, ENUSIM
	Technical abatement performance	Low	MARKAL, ENUSIM
Barriers	Sector specific barriers	Low	2050 pathways analysis
	Sector specific enablers	Low	2050 pathways analysis
	Technology specific barriers	Low	ECA

Energy trends

The data coverage on energy consumption trends within the other manufacturing sector is very low. Information is available from audited primary datasets but only at an aggregate level. CCA sector coverage is likely to be negligible. It may be the case that through the EUETS data is available on large combustion processes. This could provide information on heat usage and generation. The coverage for this data is unlikely to be comprehensive however. No significant further data sources could be identified covering site efficiency, heat generation and use and product substitution trends.

Abatement potential

The data coverage on abatement potential in the other manufacturing sector is very low. The industry is represented as part of an aggregate in a number of the energy models, where the source data is typically based on standard assumptions relating to industrial activity. No sector specific energy efficiency studies were identified. Overall the lack of available relevant research has meant the data quality score is low.

Barriers

Overall the data on barriers is low quality. Whilst sector specific issues have been identified in the government's 2050 pathways analysis, they are only qualitatively appraised. The only exception is ENUSIM, where data on hidden costs affects realistic abatement potential.

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