This report has been prepared for the Department of Energy and Climate Change and the Department of Business, Innovation and Skills

Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050

Food and Drink Appendices

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INDUSTRIAL DECARBONISATION AND ENERGY EFFICIENCY ROADMAP TO 2050 – FOOD AND DRINK

APPENDIX A - METHODOLOGY

APPENDIX A METHODOLOGY

The overall methodology used in this project to develop a decarbonisation roadmap for the food and drink sector consists of four stages:

(1) Evidence gathering and processing based on literature, interviews and workshops
(2) Modelling of draft pathways, including scenario testing and sensitivity analysis
(3) Testing and developing final pathways
(4) Creating a sector vision for 2050 with main conclusions and recommendation of next steps

This methodology is illustrated in Figure 1 and summarised in the report. A detailed description is given in this Appendix.

An important aspect of the methodology has been Stakeholder Engagement to ensure that all implicated parties have been invited to participate and contribute. We have worked closely with FDF, SWA, BBPA, Dairy UK and AIC to identify and invite the right people from the sector. In addition we have worked with the Department of Energy and Climate Change (DECC) and the Department for Business Innovation and Skills (BIS) to identify appropriate academic and other stakeholders, such as financial industry personnel, to participate and contribute.

Figure 1: Roadmap methodology

1. Evidence Gathering

Evidence gathering focused on technical and social and business evidence, and aimed to acquire information about:

- Decarbonisation options (i.e. technologies)
- Enablers and barriers to decarbonisation and energy efficiency
- Background to the sector
- Current state and future changes within the sector
- Business environment and markets
- Potential next steps

This evidence was required either to answer the principal questions directly, or to inform the development of pathways and the sector vision for 2050. The evidence was developed from the literature review, interviews, surveys and evidence gathering workshops. By using these different sources of information, the evidence gathered could be triangulated to improve the overall research. Themes that were identified during the literature review could subsequently be used as a focus or a starting point during the interviews, surveys and workshops. The data from the literature could be subjected to sensitivity testing by comparing it with information from the interviews, surveys and the workshops. In a similar way, information gaps during the interviews, surveys and workshops could be populated using literature data.

The different sources of evidence were used to develop a consolidated list of enablers and barriers for decarbonisation, and a register of technical options for the food and drink sector. This information was subsequently used to inform the development of a set of pathways to illustrate the decarbonisation potential of the food and drink industry in the UK.

The evidence gathering process was supported by high levels of engagement with a wide range of stakeholders, including industry members, trade association representatives, academics and members of DECC and BIS.

The evidence gathering exercise was subject to inherent limitations based upon the scale of activities and sample sizes that could be conducted within the time and resources available. The literature review was not intended to be exhaustive and aimed to capture key documentation that applied to the UK. Due to the size and diversity of the food and drink sector, companies interviewed represented only a minor amount of carbon emissions produced in the UK sector. The interviews included UK decision-makers and technical specialists in the food and drink sector, and were conducted to provide greater depth and insight to the issues faced by companies. However, because many UK food and drink companies are rather small, it was difficult to gain involvement in a project that focuses on decarbonisation strategies towards 2050. The small companies are focusing on production and competition, not on long-term energy and environmental policies. This aspect also applied to workshop attendees.

The identification of relevant information and data was approached from a global and UK viewpoint. The global outlook examined dominating technologies and process types, global production and CO_2 emissions (in the EU-28) and the global outlook to 2050, including the implications for food and drink producers and consumers, and production and demand uncertainties. The UK outlook examined the sector structure, recent history and context including consumption, demand patterns and emissions, the business environment, organisational and decision-making structures and the impacts of UK policy and regulation. The major UK food and drink producers and their key sites, dominant technologies and processes were also reviewed.

The food and drink sector is very diverse with many subsectors. Each of these subsectors has very specific processing technologies, although some common technologies can be identified throughout the entire sector. The energy-saving opportunities for the sector distilled from the literature review, interviews and workshops were classified into six categories: general energy efficiency, energy-efficient technologies, IEEA (Industrial Energy Efficiency Accelerator projects – carried out by Carbon Trust) technologies, low-carbon energy sources, supply chain, and carbon capture (CC).

2. Literature Review

A literature review was undertaken on the food and drink sector. Its aim was to help to identify options, enablers and barriers for implementing decarbonisation throughout the sector. It sought to answer the Principal Questions, determined the enablers and barriers for implementing decarbonisation and identified what are the necessary conditions for companies to invest and considered carbon management as a strategic issue to determine appropriate technical options for the sector.

The literature review covered over 150 documents. This was not a thorough literature review or Rapid Evidence Assessment (REA) but a desktop research exercise deemed sufficient by the project team[1] in its breadth and depth to capture the evidence required for the purpose of this project. Based on the table of contents and a quick assessment (10 to 30 minutes per document), criteria were defined to identify which documents were to be used for the detailed analysis and evidence gathering (see section 3 of APPENDIX A). Where literature was deemed significant and of good quality, it was read and results were gathered on the principal questions.

The review has drawn on a range of literature (published after 2000), that examines energy efficiency and decarbonisation of the sector and also wider reviews, studies and reports deemed relevant to energy-intensive industries overall. Sector-based and academic literature was also added. The documents are listed in section 6 of the main report.

The literature review was conducted in the following phases:

- Broad literature review and information or data collection
- Detailed literature analysis on technical points of note
- Identification of decarbonisation options and associated drivers or barriers
- Information on adoption rate, applicability, improvement potential, ease of implementation, capex, Return on Investment (ROI) and the saving potential for all options where available
- Construction of decarbonisation options list for short- (2015-2020), medium- (2020-2030) and long-term (2030-2050)
- Provision of information on strengths, weaknesses, opportunities, threats, enablers and barriers. This information was used in the evidence gathering workshop as a starting point for discussion. It provided evidence to support the development of a consolidated list of enablers and barriers for decarbonisation and, subsequently, to inform the list of the possible technological options and pathways that would lead to decarbonisation

	Details
Main focus **(all in the food and drink sector)**	Energy efficiency improvements CO_2 and carbon reduction Fuel switching
Secondary focus	Drivers, barriers, policy Carbon capture and storage (CCS)
Excluded	Alternative trends in food and drink production District heating Technologies not applicable in UK food and drink sector

Table 1: Scope of review

3. Criteria for Including Literature

As described earlier, the literature review followed a quick assessment process. General criteria used for including or excluding literature are shown in Table 2.

	Considerations	Final criteria
Literature value	Preference was given to official publications, such as academic papers or governmental publications. Information from food and drink suppliers (grey	Preference was given to published papers: the main source was ScienceDirect and published official

[1] DECC, BIS and the consultants of PB and DNV GL.

	literature) was interesting as sector-related info. However, as there is no objective standard with which to compare this information, no extensive search in this domain was executed. The grey literature was used as input to the workshops.	reports.
Time period to be covered	Given the fact that the European Energy Directive (end 2012) is a recent factor in the energy-related political landscape, preference was given to information which was (very) recently published. Some valuable, but older, information was included, as technology penetration is conducted at different speeds throughout the food and drink sector	No constraint was set on the date of the publication, but older information was given a lower quality rating, due to its lower relevance.
Geographical area	Preference was given to the UK industry, with a broader look to Europe, as the technology competition in this area is the most prominent.	No geographical exclusion criteria were used, but information on the UK food and drink was given a higher quality rating, due to its higher relevance.
Sector specifics	Considering the wide range of processes used by all subsectors in the UK food and drink sector, almost no technologies could be excluded.	No discrimination in research was used.
Language	As the majority of information is in English, no special attention was given to publications in other languages.	The search was limited to papers in English, but where easily obtainable qualitative information was found in other languages, this was included[2].

Table 2: High-level selection criteria

For academic literature, the primary source was ScienceDirect. Of the documents that came on top in the search result (typically the first 25 papers), a skim-read of the abstract decided on the relevance of the paper.

A total of more than 150 papers, official publications and grey literature experts on food and drink were collected using this search methodology. The quality, source and objectivity of each document was analysed by reading the abstract (where present), followed by a skim-read of the document.

Each document was given a score on different aspects of relevance:

- Category: is the content of the document focusing on technology, drivers or barriers or policy-related aspects
- Affiliation: what is the source of the document: academia, governance or is it sector-based
- Financial-technical evaluation criteria present (YES/NO)
- Overall quality of the document (+/++/+++)
- Relevance for the UK food and drink sector (0/+/++/+++)
- Information on technological aspects (0/+/++/+++)
- Information on drivers and barriers (0/+/++/+++)
- Information on policy/legislation (0/+/++/+++)

[2] Some valuable references are in Dutch.

- Document relevant for developing scenarios (0/+/++/+++)

Based on all these aspects, the document was given a relevance classification: ‘high’, ‘medium-high’, ‘medium-low’ or ‘low’.

The approach to selecting and categorising literature is depicted in Figure 2.

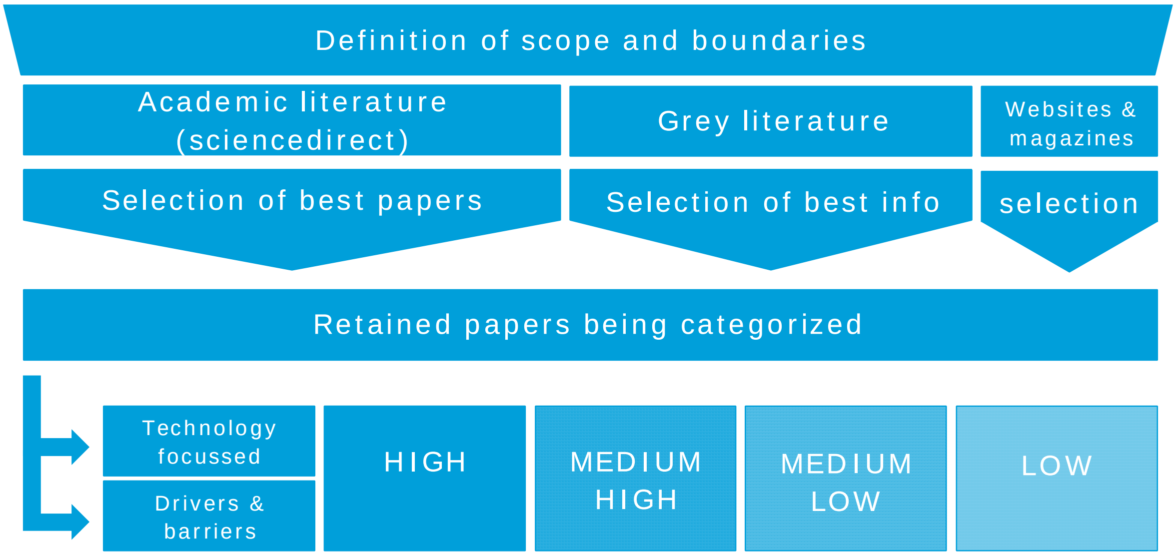

Figure 2: Diagram of the selecting and categorising process

All documents categorised as ‘high’ and ‘medium-high’ were read in detail, assessed and then included in the literature review process. The documents categorised as ‘medium-low’ and ‘low’ were read and assessed in part and only included if a significant reason for inclusion was found.

Energy saving measures (if present) were listed from each document included in the review process and this list was used to construct a decarbonisation options list for short- (2015-2020), medium- (2020-2030) and long-term- (2030-2050) timelines.

NOTE: Additional and specific information or data was added to the overall review process from e.g. stakeholder input datasheets and as a result of following citation trails, expert knowledge and further targeted searches and recommendations.

Method of Analysing Literature

The following method was used to go through the selected literature:

1. Reading and noting of the abstract (or summary) followed by review of the document in detail to extract any relevant information on sector description or outlook and information or data on energy and carbon reduction measures
2. Relevant information (if appropriate) was extracted from other sources (or referred to) and document citation trails (if appropriate) were checked for further relevant information or data
3. Incorporation of the documents into the literature review and collating of the most relevant information or data on energy and carbon reduction measures
4. Energy savings, where possible, were preferably extracted as a percentage, or as a specific energy saving per relevant unit
5. For financial savings, the amounts were kept in their original currency

4. Technical Literature Review

Identifying Literature

The primary aim of the literature review has been to gather evidence on technical potential and options (under different timelines) in order to inform the opportunities and challenges associated with the decarbonisation of energy use and improved energy efficiency for the food and drink sector in the UK.

In parallel to the above review process, a number of key academics were identified to participate and provide perspectives on current research and to provide additional input and feedback. This was to ensure that the appropriate literature and research had been identified, screened and included.

Research Questions

The evidence review addressed the following research questions:

TECHNICAL POTENTIAL: What existing research is there on the technical potential for improving the energy efficiency and lowering the carbon footprint of the food and drink Industry to 2050? What generic and specific technical measures exist and what is their potential?

TECHNOLOGY COSTS: What research is available on the costs of these technical measures, and what does it tell us?

DRIVERS or ENABLERS: What does research tell us about the drivers or enablers for organisations in the food and drink sector to decarbonise their energy use? What are the perceived benefits for industrial organisations to decarbonise their heat use?

BARRIERS: What does research tell us about the barriers for organisations limiting effective decarbonisation of their energy use?

PRINCIPAL QUESTIONS: Check for other links to issues raised by principal questions.

SWOT analysis: Check for any information using terms strengths, weaknesses, threats and opportunities.

Information Found by the Consortium during Technical Literature Review

A number of additional documents were identified during the course of the literature review. These documents were identified through Google or ScienceDirect and through the Pulp and Paper sector team. The search terms used in ScienceDirect and Google were:

- “food and drink”
- “food and drink” AND “UK”
- “food and drink” AND “decarbonisation”
- “UK food (processing) sector” AND “carbon/energy savings”
- “UK drink sector” AND “carbon/energy savings”
- “UK sugar sector” AND “carbon/energy savings”
- “UK ambient food sector” AND “carbon/energy savings”
- “UK baking sector” AND “carbon/energy savings”
- “UK cereal sector” AND “carbon/energy savings”
- “UK confectionary sector” AND “carbon/energy savings”
- “UK frozen and chilled food sector” AND “carbon/energy savings”
- “UK glucose and starch sector” AND “carbon/energy savings”
- “UK milling sector” AND “carbon/energy savings”

- “UK oils and fats sector” AND “carbon/energy savings”
- “UK pet food sector” AND “carbon/energy savings”
- “UK soft drinks sector” AND “carbon/energy savings”
- “UK dairy sector” AND “carbon/energy savings”
- “UK spirits sector” AND “carbon/energy savings”
- “UK animal feed sector” AND “carbon/energy savings”
- “UK brewers sector” AND “carbon/energy savings”
- “UK red meat (BMFA) sector” AND “carbon/energy savings”
- “UK poultry meat sector” AND “carbon/energy savings”
- “UK maltsters sector” AND “carbon/energy savings”
- “UK renderers sector” AND “carbon/energy savings”
- “UK craft baking sector” AND “carbon/energy savings”
- “UK SME food sector” AND “carbon/energy savings”
- “UK food and drink sector” AND “drivers/barriers”

Other documents in ScienceDirect were found by checking the references of the papers found by the above searches.

The results of the technical literature review are summarised in Figure 3.

Division	Summary of strength of evidence on energy efficiency in food and drink sector								
	Number of information sources reviewed					Strength of the evidence			
	Academic searches	Direct website searches	expert reviewer	grey literature	Total	HIGH	MEDIUM HIGH	MEDIUM LOW	LOW
General	5	4	12	0	21	11	5	3	2
Technologies	22	10	29	5	66	32	14	12	8
CO_2 & CCS	4	4	6	0	14	1	6	3	4
Enablers/barriers	1	0	0	0	1	1	0	0	0
Social and business	7	10	0	25	42	6	20	13	3
Market	6	4	7	0	17	10	4	1	2

Figure 3: Overview of literature review

A complete reference list is available in **Error! Reference source not found.** 6 of the main report.

5. Social and Business Literature Review

In addition to the work and processes described in the technical literature review, the social and business literature review key points and additions are:

- We reviewed over 40 documents (some of them the same as the technical literature review) to create a broad overview of the sector SWOT and identification of drivers and barriers to energy efficiency improvement and decarbonisation, and identification of main uncertainties in generic and business environment.
- The literature review included documents listed in the ITT (invitation to tender) as well as grey literature from Trade Associations, companies, DECC and BIS. Specific search terms were used which were agreed with DECC to identify the key enablers and barriers.
- We used a systematic and structured approach to the literature review. The criteria for assessing the relevance of the literature were defined to determine whether they address the key principal questions. The literature identified was analysed using a quick assessment process to identify the most relevant information on SWOT, enablers and barriers to decarbonisation.
- Based on table of contents and a quick assessment, we presented the results in a table as below. The analysis resulted in the identification of documents to be used for detailed analysis and evidence gathering. Where literature was deemed significant and of good quality (three stars or above), the literature was read and reviewed and results were gathered on the principal question areas.

	Year	Relevance	Quality	Characteristics	SWOT, Drivers and Barriers	Uncertainties future trends	Options	pathways
Title 1		+++	++	0	++++	++	0	++++
…		++	+++	++	0	+++	+	+
…		+	++	+	0	++++	++	0
Title 10		++	++++	+++	++	+++	+++	++

Table 3: Literature review assessment process

0= very low, ++++ very high

The outcome of the literature review was a comprehensive list of strengths, weaknesses, opportunities, threats, enablers and barriers which were used in the evidence gathering workshop as a starting point for discussion and voted on to check which ones were most important.

6. Interviews

The evidence gathering stage of the project also involved a series of interviews. These aimed to obtain further details on the different subsectors within the food and drink industry and to gain a deeper understanding of the Principal Questions, including how companies make investment decisions, how advanced technologies are financed, the companies' strategic priorities and where climate change sits within this.

Due to the size and diversity of the food and drink sector, companies interviewed represented only a minor amount of carbon emissions produced in the UK sector. It was agreed to undertake six interviews for the food and drink sector. We identified the proposed interviewees in liaison with FDF, DECC and BIS, and in accordance with the pre-defined criteria.

Six face-to-face interviews were completed and the following organisations were interviewed:

- FDF (Food and Drink Federation) – Environment and Energy Policy
- Nestle – Environmental Manager for the UK
- Dairy Crest – Environmental Manager
- Coca-Cola Enterprises - Environmental Manager
- British Sugar – Environmental Manager
- EBLEX – Manager

Comments collated via FDF, SWA, BBPA, Dairy UK, AIC, the surveys, the workshop and subsequent email correspondence were also used as part of the evidence gathering process.

Interviewees were interviewed using the 'interview protocol' template, developed in liaison with DECC and BIS. The interview protocol was used to ensure consistency across interviews, to ensure that the interviews could be used to fill gaps in the literature review, identify key success stories of decarbonisation, and extract the key social and business barriers of moving to low-carbon technologies. The interview protocol can be found further in this section.

Assumptions

Going into each interview, a number of assumptions were made to refine the approach being taken:

1. Results from the literature review are available and partially well covered. Well covered areas are not addressed during the interview. Results may include:
    a. Options register of technical options
    b. Sector and subsector characteristics
    c. Sector SWOT analysis
    d. Main trends and drivers
    e. Some hurdles to and barriers for change or energy or carbon reduction
2. Preparation of interviews includes rapid review of website and annual reports information related to business and energy and emissions reduction strategies.
3. The technical review covered any gaps in data or information (e.g. specifically related to that company's data) which may be appropriate to obtain during the interview process.
4. Interviewee role is reviewed prior to conducting the interview.
5. All interviews are conducted by interviewers in their own proficient way of dealing with issues around openness, consent, and follow-up.
6. There might be follow-up with interviewees to obtain additional information discussed during the interview.

Interview Protocol

Preparation

1. Interviewee identification

Interviewees are identified in liaison with DECC and BIS in order to achieve good coverage of each sector. The steps taken to identify relevant candidates are:

- Identify the number of subsectors using SIC (standard industrial classification) codes listed in the ITT or another appropriate subsector division
- Where possible, subsectors were grouped based on similarities in products or production techniques to reduce the number of subsectors
- Identify which subsectors or organisations were most significant using the following criteria:
    - Size (e.g. by revenue or emissions)
    - Innovation level of companies
    - Whether headquartered in UK
    - Level of supply chain integration
- Select candidates best positioned to represent the views of the breadth of subsectors

2. **Interview preparation**

The focus of each interview is to be informed by research of the key issues and challenges, successes and opportunities faced by each sector and an understanding of the specific knowledge held by the interviewee. The research incorporates:

- Social business literature review
- The findings of the technical review and decarbonisation options identified
- Review of company websites, annual reports and other materials relating business and emissions reduction strategies
- Assessment of the role of the interviewee and extensiveness of their knowledge
- Review of website, ONS data, IBIS data and annual reports information related to business and energy and emissions reduction strategies.
- Development of the options register

3. Interview format

Introductions

Interviewer sets out the project context and interview agenda.

Goals

Interviewer introduces the goals of the project as follows:

1. To determine the current state, ambitions or plans, successes and problems or challenges of each of the interviewee's organisation or sector with regard to energy use, energy and carbon reduction:

a. Identify and analyse examples of the implementation of energy and carbon reduction projects to deliver insight in the problems and barriers at a company level

b. Develop an understanding of the decision-making processes

c. Develop an understanding of the relationship between energy or carbon strategy and business strategy

2. To develop insight into the energy and carbon reduction options available to the organisations or sector and their potential:

   a. As currently deployed by organisations

   b. As an option to be deployed in the future

3. Understanding of the main drivers and barriers for change in general and with regard to energy and carbon reduction in the sector

4. To develop insight into the specific characteristics (strengths, weaknesses, opportunities and threats) of subsectors (where required)

Existing and future strategy for energy and carbon reduction

Interviewer to engage the interviewee on the focus of their organisations energy and carbon strategy using the following questions:

1. What is your organisations strategy for energy and carbon reduction? (If the strategy is clear, summarise and ask for confirmation). Cover the following sub-questions:

   a What are the main elements of the strategy?

   b How far in advance are you planning the company's energy efficiency strategy?

   c In your opinion, what are the enablers or challenges for the strategy?

      i) Please specify why:

         1. Constrained finance for funding for investments internally or externally

         2. Etc.

2. Do you consider your organisation as a leader (innovator or early adopter) or as a follower (early, late majority) on energy and carbon reduction? Cover the following sub-questions:

   a. Can you give one or more example(s) of actions undertaken by members of your organisation that fit with the stated market position?

   b. Do you expect the organisation's position with regard to energy and carbon reduction to change?

   c. Please state why your organisation is or is not a leader.

3. What energy and carbon projects have you implemented the last five years and why? What energy and carbon projects have you not implemented the last five years and why?

   Guidance for interviewer: use the prepared options register (prepared by technical lead and sector team) to identify energy and carbon reduction options. For parts of the list that are not covered, challenge the interviewee to identify options that could be valuable. With front runners place emphasise on more innovative options.

4. How important is energy and carbon reduction for your organisation? Please address how the carbon and energy strategy fits into wider business strategy and the extent to which it is embedded.

Stories (interviewees not self-identified as leaders)

Interviewer to lead discussion of a story or example related to an energy or carbon reduction project that went well and another that did not

Stories: Questions for leaders (only for self-identified leaders)

Interviewer to lead discussion of a story or example related to an energy or carbon reduction project using the questions below:

1. What energy and carbon reduction options have been implemented, why, when and where?
2. Can you tell the story of a project from the initial idea generation until now? Ensure this covers how ideas were generated (i.e. the step before any appraisal of options takes place):
    a. What was the timeline, sequence of events?
    b. Cover: idea generation, feasibility study (technological, financial, and organisation), decision-making, board presentation, and implementation
    c. What was your process for making a case for an investment and who was involved? Consider: key factors during decision-making, required payback, main perceived or actual risks, influence of alternative options for investment, financial and non-financial factors
    d. What were the critical moments (breakthroughs, barriers)?
3. What was the original position of the main stakeholders to the energy carbon project? Did their attitudes towards the subject change? How?
4. Why do you consider this story as a success or an area for improvement?
5. What are the main conclusions you can draw from this story - positive and negative?
    a. Lessons for future action?
    b. Main drivers and barriers for energy and carbon reduction in your company?
    c. Lessons for the way of organising energy and carbon reduction options within you company?
    d. Conclusions regarding potential reduction targets on short-, medium- and long-term?
    e. How well did the decarbonisation option work in practice, in relation to the anticipated performance?
6. Can any reports or presentations on this innovation be supplied?

Business Environment: value chain and capacity for innovation

Interviewer to ask the following questions:

1. What do you consider to be the main drivers for energy and carbon reduction in the sector?
   a. What are main characteristics of the main parts of the production process? Following the structure of the options register:
      i. Ask specific questions on any elements not covered in the desk research
      ii. Ask specific questions on the characteristics of the subsector (input, process, output, energy use, value chain, competitive forces)
   b. What do you perceive as the strengths and weaknesses of your value chain?
   c. What have been the main changes in the value chain over the last ten years?
   d. What innovations do you expect to see in the value chain in the coming 10/20/30 years?
   e. What are possible game changers for the value chain or sector?
2. Main innovators or early adopters in the sector:
   a. Who influences action (whom or what are they listening to? Why?
      i. Organisations and people within organisations (role or function)?
      ii. Within or outside the sector (other sectors, academics, non-government organisations, politicians, etc.)?
3. Questions on the dimensions of innovations[3] . These questions will be on a multiple choice list (answer categories strongly disagree, disagree, neither agree or not agree, agree, strongly agree[4]). After filling the list, ask for clarifications and examples that underpin answers in the following areas:
   a. Technical: networks with other companies, academics, knowledge of competitive and emerging technologies, participation in R&D, pilots, experiments
   b. Human capital: improvement projects, multi-disciplinary teams, training on innovation, change or improvement
   c. Organisation: horizontal communication lines, clear goals or responsibilities, customer focus
   d. Management: clear performance criteria for projects, structural follow up of main improvement projects in management meeting, clear status information on projects
4. (Optional) Please set out a characteristic story of a (successful) sector and subsector that implemented a change or innovation related to energy or carbon reduction. This question should be asked if consortia or sector teams feel a need to get a better overview of success stories. The question is relevant because in most business environments managers are influenced most by their peers.

[3] Questions are asked to get a better (and broad overview of space or possibilities for change (not only including investments but also the change that potential of option will materialise.

[4] This way of working is chosen to be able to just cover the field quickly and get a quick first idea what they consider the important aspects so we can spend as much time as possible on this. We normally don't use the survey results to collect quantitative answers to these.

Enablers and barriers for sector change

Interviewer to lead a summary discussion of the main drivers and barriers for sector change (general and or specific for energy and carbon reduction) using the following questions:

1. What do you consider the main drivers for change in the sector?

   a. Please state specific drivers in the following fields: social, policy, technical regulatory factors

   b. Interviewer to review the pre-prepared list of main driver and check seek further detail from the interviewee

2. What do you consider the main barriers for change in the sector?

   a. Please state specific barriers in the following fields: social, policy, technical regulatory factors

   b. Interviewer to review the pre-prepared list of main barriers and seek further detail from the interviewee

Function of Interview Template and Protocol:

The interview template was designed to collect, build upon and collaborate specific answers to principal questions which are not covered by results of desk research. The general timeline of one interview is illustrated below:

Intro	5-10 minutes
Current state and plans energy and carbon reduction	20-30 minutes
Stories of energy or carbon reduction	30-45 minutes
Business environment and innovation power	15-20 minutes
Drivers and hurdles for sector change (to test survey or workshop questionnaire)	If time left

Table 4: General interview timeline

7. Survey

As part of the evidence gathering exercise and to help build a list of the enablers and barriers, a short bespoke survey was conducted with some of the many UK food and drink manufacturing industries.

The survey was distributed to general managers and energy or environment managers from member organisations of the UK FDF, Dairy UK, Scotch Whisky Association (SWA), Agricultural Industries Confederation, British Beer and Pub Association (BBPA), EBLEX and MAGB. The questions in the survey were tailored to manufacturers, and were developed in consultation with DECC and FDF.

The questions were drawn up in consultation with DECC and FDF. The key questions focused on the respondents view on the level of impact of the top enablers and barriers on the implementation of energy and carbon reduction options as identified from the interviews and literature review. .

The main objectives of the survey included:

a. Collect background information such as role, size of organisation represented and innovation adoption appetite
b. Assess the impact on the implementation of energy and carbon reduction technologies of 20 enablers and 20 barriers identified from the literature review and interviews
c. Prioritise top five strengths, weaknesses, opportunities and threats of the sector
d. Assess current conditions and capacity of the organisations to respond to decarbonisation

Survey Questions
1. What subsector are you working in or what is your relation to the food and drink industry?
2. What is the number of employees within your organisation?
3. What is your function within your organisation?
4. How would you describe your company's position in the sector regarding carbon and energy reduction? Please see the definitions below for reference.
5. What impact do the following **enablers** have in relation to implementing energy and carbon reduction technologies in your organisation? (A list of 15 enablers identified from the literature review was provided for assessment).
6. Are there any additional enablers that you think are relevant? Please provide details of these and an impact score based on the same scale.
7. What impact do the following **barriers** have in relation to implementing energy and carbon reduction technologies in your organisation? (A list of 15 barriers identified from the literature review and interviews was provided for assessment).
8. Are there any additional barriers that you think are relevant? Please provide details of these and an impact score based on the same scale.
9. Please select the 5 **strengths** that are the most relevant to your organisation. (A list

	of 15 strengths identified from the literature review and interviews was provided for assessment).
10.	Please add any other strengths of your organisation that are not included in the list.
11.	Please select the 5 **weaknesses** that are the most relevant to your organisation. (A list of 12 weaknesses identified from the literature review and interviews was provided for assessment).
12.	Please add any other weaknesses of your organisation that are not included in the list.
13.	Please select the 5 **opportunities** that your company could potentially explore to maximise the implementation of energy and carbon reduction technologies. (A list of 15 opportunities identified from the literature review and interviews was provided for assessment).
14.	Please add any other opportunities of your organisation that are not included in the list.
15.	Please select the 5 **threats** that will potentially hinder your organisation in implementing energy and carbon reduction technologies. (A list of 14 threats identified from the literature review and interviews was provided for assessment).
16.	Please add any other threats of your organisation that are not included in the list.
17.	Please assess to what degree each statement is true for your organisation. • We have well defined goals or objectives or targets on energy and carbon reduction • Our goals or objectives are translated to targets at site level • We have a systematic decision-making process for new initiatives with regards to energy and carbon reduction • Our decision-making process works well for new energy and carbon reduction initiatives • We track progress of energy or carbon improvement projects in management meetings • We have specific roles or allocated responsibilities within the company with regards to energy or carbon reduction • We have strong communication and information sharing channels that support the successful implementation of options with regards to energy and carbon reduction • We understand which energy and carbon reduction technologies can be implemented in our organization • We have sufficiently skilled workforce to implement and handle energy and carbon reduction technologies

Table 5: Survey questions for the food and drink sector

For questions 5, 6, 7 and 8, respondents were given the following impact scale for assessing each enabler and barrier:

Score	Definition
1	No impact
2	Limited impact
3	Medium impact
4	High impact

Table 6: Scoring table

The resulting impact scores for each enabler and barrier can be found in appendix B. The percentage of respondents who selected the impact level has been provided for each enabler and barrier.

8. Evidence Gathering Workshop

The evidence gathering stage of the project also involved Workshop 1, the 'Information Gathering Workshop'.

We worked with FDF, SWA, BBPA, Dairy UK, AIC, DECC and BIS to identify the most relevant attendees for the workshop. The research work already undertaken as part of the literature review and interviews were used to inform the content of the workshop.

The workshop was divided into two key activities. The first activity focused on reviewing all potential technological options for decarbonisation and identifying adoption rate, applicability, improvement potential, ease of implementation, capex, ROI, saving potential and timeline for the different options. This was done through two breakout sessions, one focused on collecting more data and the other focused on the timeline under different scenarios. The second activity involved splitting participants into five groups to discuss and vote on the enablers and barriers. Participants were also asked if they had any other enablers and barriers to be included. The aim of this section of the workshop was to prioritise the enablers and barriers and begin to consider how to overcome them (so that this could feed into later work on the options register, pathways and next steps).

We recognise that the voting process was based on initial reactions and that everyone voting may not have the expertise required on specific technical solutions to decarbonisation. In order to counter this limitation, FDF provided a validation of the options data after the first workshop.

The outcome of the evidence gathering workshop (and all evidence gathering stages of the project) was a consolidated list of enablers and barriers, and a more complete list of possible technological options with a suitable timeline for their implementation.

9. Pathways

A pathway is a combination of different decarbonisation options, deployed under the assumed constraints of each scenario that would achieve a decarbonisation level that falls into one of the following decarbonisation bands:

- 20-40% CO_2 reduction pathway
- 40-60% CO_2 reduction pathway
- 60-80% CO_2 reduction pathway

In addition, two purely technology-driven pathways were developed: a business as usual (BAU) pathway and a maximum technical (Max Tech) pathway. The BAU pathway consisted of the continued deployment of technologies that are presently being deployed across the sector. The Max Tech pathways - with and without - included a technology or technology combination that would achieve the maximum CO_2 reduction possible within the sector, given constraints of deployment rates and interaction. The pathways have not been optimised to achieve a certain decarbonisation level.

10. Pathways Development and Analysis

Overview

Pathways were developed in an iterative manual process in order to facilitate the exploration of uncertain relationships that would be difficult to express analytically. This process started with the data collected in the evidence gathering phase. This data was then challenged and enriched through discussions with the sector Team and in the first workshop.

Logic reasoning (largely driven by option interaction and scenario constraints), sector knowledge and technical expertise were applied when selecting options for the different pathways under each scenario. For example, incremental options with lower costs and higher levels of technical readiness were selected for the lower decarbonisation bands, whereas more ‘disruptive’ options were selected for the higher decarbonisation bands in order to reach the desired levels of decarbonisation. These pathways were challenged by the sector Team, modelled and assessed under the three scenarios and finally challenged by the Stakeholders participating in the second workshop. This feedback was then taken into account and final pathways were developed. All quantitative data and references were detailed in the Options Register and relevant worksheets of the model.

It is important to keep in mind that the pathways results are the outcome of a model. As with all models the accuracy of the results is based on the quality of the input data. There are uncertainties associated with the input data and the output should therefore be seen as indicative and used to support the Vision and Next Steps, not necessarily to drive it. Also the model was a simplification of reality, and there are likely to be other conditions which are not modelled.

The analysis only produced results (pathways) which were iterative inputs of the model operator, without any optimisation.

Process

1. The gathered evidence (from literature review, sector team discussions, stakeholder feedback and judgement) was consolidated into a condensed list of options.
2. Timing and readiness of options was developed by the sector Team and during the first workshop, based on evidence from literature, sector knowledge and technical expertise.
3. Options were classified as energy efficiency improvements (CCA focus), energy efficiency technologies, Industrial Energy Efficiency Accelerator projects (IEEA) technologies, low-carbon energy sources, and supply chain.
4. BAU and Max Tech options were chosen and rolled out to the maximum level and rate allowable under the current trends scenario.
5. Options were added to the BAU pathway or reduced or taken out of the Max Tech pathway until each intermediary pathway band was reached.
6. Technical constraints and interactions across the list of options were taken into account when selecting options and deployment.
7. The deployment was adjusted to account for the output of the social and business research as well as current investment cycles.
8. Pathways were modelled under the current trends scenario, accounting for changes in production and the carbon emissions of the electricity grid.
9. The results were reviewed and modifications made to the deployment, applicability and reduction potential for any options that appeared to be giving an unexpected or unusual result.
10. Further changes to option choices were made as required through iterations of points 5-9.

11. Revised pathways under current trends were produced for presentation at the second workshop.
12. Feedback on pathways was used to make any further necessary adjustments to the pathways under current trends.
13. The final pathways developed under current trends were used as a basis for the development of pathways under challenging world and collaborative growth scenarios.
14. Deployment of each option under challenging world and collaborative growth was adjusted according to the constraints of each scenario, including the removal of options that would not be likely under challenging world and the deployment of additional options that would become feasible under collaborative growth.
15. Roll-out for each option was adjusted within the technical and scenario constraints in order to reach each pathway band where possible. Note that not all pathway bands are possible under some scenarios.

The options are listed in appendix C.

Deployment of Options

For each pathway, options were selected and deployed over time according to their readiness level, timing constraints, and those most likely to allow the pathway band to be achieved. This process occurred iteratively, involving the sector team, trade association and other stakeholders (who contributed via the second workshop). The sector Lead provided an expert view on whether the options identified in each pathway produced a feasible pathway.

As described within the pathways section of the report, the technologies included within each banded pathway under each scenario may differ in order to meet the pathway band under each scenario.

The selection and deployment of options accounted for evidence from the social and business research, for example which options could be deployed without any changes to policy and where the deployment of options may be slowed or curtailed by identified barriers or accelerated by enablers.

Option Interaction

There were a number of possible ways in which options could interact with each other. These interaction types, and how they were dealt with in the development of pathways, are described below:

- **One option excludes another:** This is taken into account by the user in the deployment inputs in the Option Selector by ensuring that no exclusive options are rolled out to a conflicting level in the same time period.
- **One option depends upon another being adopted:** This is taken into account by the user in the deployment section of the option selector by ensuring that if any option requires a precursor, then this precursor is rolled out to the appropriate level.
- **Options are independent and act in parallel:** The 'minimum interaction' pathway curve assumes that all options are independent and their effect on energy or emissions are therefore incremental.
- **Options improve a common energy or emissions stream and act in series:** The 'maximum interaction' pathway curve assumes that the saving from each option reduces the remaining energy or emissions for downstream options to act upon.

The pathways curves included a 'maximum interaction' and a 'minimum interaction' curve. The actual pathway curve would lie between these two extremes.

Evidence Not Used in Pathways Modelling

Specific energy use of processes was considered constant in the modelling, whereas they are actually dependent on the load factor (production level) of the equipment. Increasing the production level of existing equipment would increase efficiency (in terms of kWh/tonne product or Mt CO_2 per tonne product), which should be taken into account when calculating emissions. However, a full bottom-up model would be needed, which was beyond the scope of this work.

The options were modelled with a fixed CO_2 and fuel saving as input values. As technologies mature, it is likely that these values would increase. This was not taken into account in the model, as the uncertainty of that development is high.

The adoption rates and applicability rates were used to inform deployment, but without a full bottom-up model implemented on a site-by-site basis, it was difficult to link these parameters directly to investment cycles.

11. Pathways Modelling

Scenarios

Modelling pathways starts with the development of scenarios. A scenario is a specific set of conditions external to the sector that would directly or indirectly affect the ability of the sector to decarbonise. An example of a condition in a scenario was the emissions factor of the electricity grid. Where appropriate, conditions were described qualitatively through annual trends. The scenarios analysis also included qualitative descriptions of exogenous drivers which were difficult to quantify, or for which analytical relationships to quantitative factors were indefinable.

For each pathway, the following three scenarios were tested: current trends, challenging world and collaborative growth. Scenario parameters are shown in Table 7below.

Current Trends

The current trends scenario projected moderate UK and global growth. Alongside this, international policies on climate change were assumed to develop, gradually but effectively driving down emissions.

New low-carbon generation technologies were assumed to progressively decarbonise the electricity grid to 100 g/kWh by 2030.

food and drink production was assumed to increase by 1% annually. It was assumed that domestic population growth rates, affecting domestic demand, would remain stable and the UK food and drink export market would grow at a similar rate. Other governments were assumed to start taxing carbon.

Challenging World

The challenging world scenario was characterised by lower global growth rates. Climate change was assumed to have a lower profile than at present, so that there would be less effective action to reduce emissions.

New low-carbon generation technologies were assumed to progressively decarbonise the electricity grid to 200 g/kWh by 2030.

The UK food and drink production over the period was assumed flat (0% annual growth), subject to a slower domestic population growth rate and more intense international competition resulted in a pessimistic business environment for the sector. Innovation is assumed to be stifled as firms concentrate on survival in industry producing low returns.

Collaborative Growth

The collaborative growth scenario was represented by higher levels of global growth and concerted action to reduce carbon emissions.

New low-carbon generation technologies were assumed to progressively decarbonise the electricity grid to 50 g/kWh by 2030.

The UK food and drink industry sees growth at 2% per year, largely driven by an increase in both domestic and international population growth rates together with a shift towards more advanced processes, growth in higher added value and lower carbon footprint products. The business environment was assumed to be positive and food and drink plants of all sizes working at the optimum capacity. A favourable global carbon price was assumed to be in place.

	challenging world	current trends	collaborative growth
International consensus	National self-interest	Modest	Consistent, coordinated efforts
International economic context	More limited growth, some unstable markets, weakening of international trade in commodities	Slow growth in EU, stronger in world, relatively stable markets	Stronger growth in EU, stable markets, strong international trade.
Resource availability and prices	Strong competition, High Volatility High price trends.	Competitive pressure on resources. Some volatile prices Central price trends.	Competitive pressure on resources. Some Volatile prices Central price trends.
International agreements on climate change	No new agreements. Compliance with some agreements delayed	Slow progress on new agreements on emission reductions, all existing agreements adhered to.	Stronger worldwide agreements on emission reductions, consistent targets for all countries
General Technical Innovation	Slow innovation and limited application	Modest innovation, incidental breakthroughs	Concerted efforts lead to broad range of early breakthroughs on Nano, bio, green and ICT technologies.
Attitude of end consumers to sustainability and energy efficiency	Consumer interest in green products only if price competitive. Limited interest in energy efficiency.	Limited consumer demand for green products, efficiency efforts limited to economically viable improvements	Consumer willing to pay extra for sustainable, low carbon products. Strong efforts to energy efficiency even where not cost effective.
Collaboration between sectors and organisations	Minimal joint effort, opportunistic, defensive	Only incidental, opportunistic, short term cooperation	Well supported shared and symbiotic relationships
Demographics (world outlook)	Declining slowly in the west Higher growth elsewhere	Declining slowly in the west Modest growth elsewhere	Stable in the west Slowing growth elsewhere

	challenging world	current trends	collaborative growth
World energy demand and supply outlook	Significant growth in demand with strong competition for resources. High dependence on imported fossil fuels	Balanced but demand growth dependent on supplies of fossil fuels from new fields.	Growing demands balanced by strong growth in supply of renewable energy, slowly declining importance of fossil fuels.
UK Economic outlook	Weaker OBR growth assumption.	Current OBR growth assumption	High OBR growth assumptions
Carbon intensity of electricity	Weakest trend of electricity carbon intensity reduction 200g/kWh at 2030	Stronger trend of electricity carbon intensity reduction 100g/kWh at 2030	Rapid decline in electricity carbon intensity 50g/kWh at 2030
CCS availability	Technology develops slowly, only becoming established by 2040	Technology does not become established until 2030	Technology becomes proven and economic by 2020
Low carbon process technology	New technology viability delayed by ten years	New technology economically viable as expected	New technology viability achieved early

Table 7: Summary of scenario context and specific assumptions applicable to the scenarios

12. Options

Classification and Readiness of Options

The food and drink sector is very diverse with many subsectors such as dairy, brewery, distilling, sugar, confectionery, bakery, rendering, meat processing, fish and seafood, poultry, malting, soft drinks, animal feed, oil and fat, glucose, canned food, ice cream and pet food. Each of these subsectors has very specific processing technologies, although there are some common technologies throughout the entire sector.

The options distilled from the literature review, interviews, evidence gathering workshop, discussions with trade associations and input from academia are presented in appendix C (the data for these options are also listed). The energy-saving opportunities are classified into six categories containing 25 options in total:

- General energy efficiency: These options were already identified under the current Climate Change Agreements, and are therefore deployed first to completely achieve the target set under the CCA for the food and drink sector, i.e. a CO_2 emissions reduction of ca. 18% by 2020 (BAU pathway under current trends scenario).
- Energy-efficient technologies: This group of options is deployed more slowly, picking up speed five to ten years after the general energy efficiency technologies.
- IEEA technologies: The development of these technologies follows slow improvement rates on average.
- Low-carbon energy sources: In this group of options, especially electrification of heat has a very high impact on the decarbonisation of the sector. Because acceptance of this option will be much higher than that of carbon capture, electrification of heat is deployed faster (especially in the collaborative growth scenario).
- Supply chain: These options develop fairly quickly, because several programmes (such as the Courtauld Commitment) put focus on waste reduction. The option with the biggest impact is reducing packaging (waste). This option also includes advanced sub-options such as nanotechnology and smart packaging. It develops rather slowly as it depends on R&D, technological improvements, government approval and acceptance.
- Carbon capture (CC): This option includes the end-of-the-chain decarbonisation of food and drink processes. Trade associations and individual company representatives were sceptical in believing that CC will develop into a mainstream solution throughout the sector. This scepticism is also related to the average size of the companies: there are only a few big companies with concentrated CO_2 emissions compared to a vast majority of small companies in the sector, and for these small companies CC would be a very expensive option (if feasible at all).

Options Processing

The options register was developed jointly by the technical and social and business research teams. This was achieved by obtaining the list of potential options from interviews, literature, asking participants at the evidence gathering workshop which options they would consider to be viable, and through receiving detailed information from FDF. The technical team drafted the first list of options. However, each option had strengths, weaknesses, enablers, and barriers which needed to be taken into account to develop and refine the Options Register to feed into the model.

A comprehensive list of enablers and barriers identified from the literature review was refined and triangulated with the evidence gathering workshop, surveys and interviews. To find the most relevant enablers and barriers for incorporating into the Options Register and pathways, enablers and barriers that were not supported by the evidence gathering workshop and interviews were removed from the list.

The impact of social and business research was captured in the options register, under the individual technologies (where possible) and in the subsequent pathways selected.

We have used the decision tree below to determine whether the social and business findings should impact upon the options and pathways. The pathways represent a selection of options, and this determines when and to what extent the options become active.

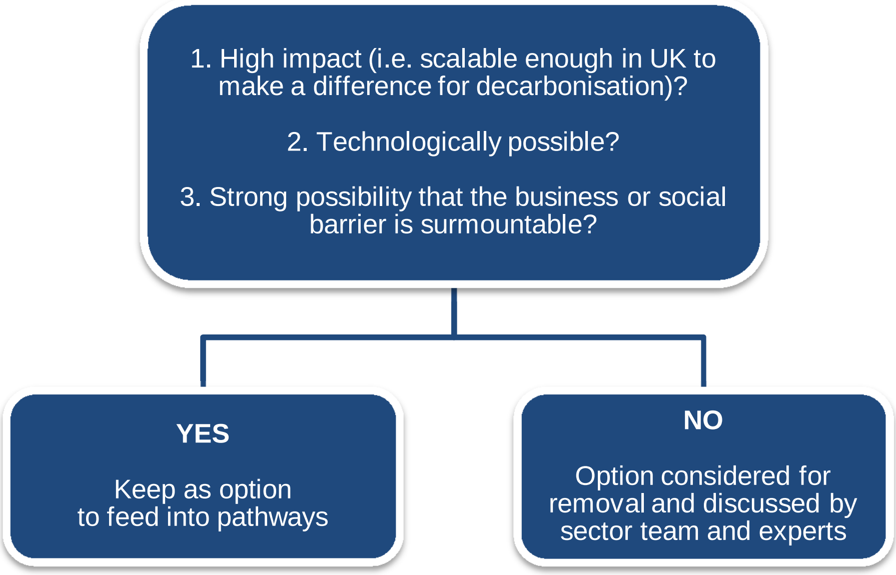

Figure 4: Social and business pathways impact tree

13. Pathway and Action Plan Workshop

The second workshop focused on reviewing the draft decarbonisation and energy efficiency pathways and identifying potential actions for delivering them. This included presenting and discussing draft pathways in groups and then asking the question, "Taking into account the identified barriers and enablers, what next steps would assist in delivering the pathways?"

The outputs of the second workshop were used to validate the pathways and to inform the conclusions of the roadmap, which include example next steps and actions.

14. Next Steps

The output of the pathway development and social and business research included identification of barriers to and enablers for:

- Implementation of the pathways
- Decarbonisation and energy efficiency in the food and drink sector more generally

To draw conclusions, the analysis of enablers and barriers is taken further by describing a list of possible next steps to be implemented by a combination of industry, government and other organisations. These actions can take the form of strategic conclusions which are high-level or longer-term, or more specific, discrete activities which can lead to tangible benefits.

The development of conclusions and next steps has considered the following:

- Actions from other food and drink decarbonisation projects
- Necessary changes in future markets, product features, business environment to enable the different pathways
- The outputs of workshops held as part of this project covering decarbonisation and energy efficiency pathways and next steps
- Actions that help maximise the success of a pathway under a range of scenarios
- Options within the pathways that are necessary for success, e.g. if a particular technology option is necessary for the success of a number of pathways, or an option has a very high decarbonisation potential, actions to implement this option are included
- Policy and regulations that could contribute to the removal of barriers or enhancement of enablers

INDUSTRIAL DECARBONISATION AND ENERGY EFFICIENCY ROADMAP TO 2050 – FOOD AND DRINK

APPENDIX B – FULL SOCIAL AND BUSINESS FINDINGS

APPENDIX B FULL SOCIAL AND BUSINESS FINDINGS

1. SWOT Outcomes

The table below highlights the top strengths, weaknesses, opportunities and threats in relation to decarbonising the food and drink sector in the UK.

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
Innovation is a key focus of the food and drink industry	A slow pace of technological change	Increase R&D activities in developing cleaner production technologies	Threat of rising energy prices
Strong commitment on climate change	Limited access to finance for R&D and technology testing	Exploit the growing consumer preference for provenance	The rising costs of raw materials
Improving resource efficiency and productivity	The sector is highly fragmented, with a very broad diversity of businesses	Improve communication and coordination of the various initiatives which already exist in the sector	Energy supply constraints and volatile prices in the UK
	Low ability to attract new highly-skilled, technical employees	Improve engagement across the supply chain and sharing of knowledge	Increased bargaining power of food retailers
Strong branding and new product development	High standards of food quality, safety and sustainability	Harmonise legislation at EU level	Food and drink manufacturing relies on very complex, often global, supply chains

Table 8: SWOT Analysis

A **SWOT analysis** is a different lens to examine the enablers and barriers and reinforce conclusions and linkages between evidence sources. It identifies how internal strengths mitigate external threats and can be used to create new opportunities, and how new opportunities can help overcome weaknesses. By clustering the various possibilities, we identified key stories from the SWOT analysis which enabled us to describe the business and market story in which companies operate. In order to understand the inter-linkages between the SWOT analysis for the sector and the key enablers and barriers we identified from the literature review, interviews, and workshop, we analysed the root causes of the enablers and barriers and linked it back to the market environment and internal decision-making. The top SWOT outcomes were identified from the literature review, reinforced in the interviews and voted on by workshop participants as the most important.

Other social and business research methods used include system analysis, root cause analysis, causal mapping, Porter's Five Forces analysis, and storytelling. **System analysis** can be used to help decision makers identify a better course of actions and make better decisions. It is a process of studying a procedure or business in order to identify goals and purposes, and to create systems and procedures that will achieve those goals most efficiently. It uses an experimental approach to understand the behaviour of an economy, market or other complex phenomenon. **Root cause analysis** is a method of problem solving that tries to identify the root causes of a problem. A root cause is a cause that - once removed from the problem - prevents the final undesirable event from recurring. **Causal mapping** is a visual representation, showing causalities or influences as links between different nodes. These maps can be used to aid strategic planning and thinking. **Porter's Five Forces** is a framework to analyse the level of competition within an industry and business strategy development. **Storytelling** is a technique that uses a clear and compelling narrative to convey a message or provide context to a conversation with the aim to engage the interviewee and encourage openness.

2. Assessing Enablers and Barriers

The first stage in our analysis was to assess the strength of the evidence for the identification of the enablers and barriers. This was based on the source and strength of evidence and whether the findings were validated via more than one information source. If the strength of the evidence was deemed high or medium high, then for the social and business research the enabler or barrier was included and information was used to support the answer to the principal question '*What are the main business enablers and barriers to decarbonisation?'*. If the strength of the evidence was deemed high or medium high for the technical options, the uncertainties in the modelling were reduced. The evidence was given a relevance classification of: 'high', 'medium-high', 'medium-low' or 'low'. The classifications are defined in Table 9.

It should be noted that the nature of the interview and workshop discussion process means that these represent the opinions and perceptions of the interviewees and workshop participants which could not always be backed up with evidence from other information sources.

The evidence was analysed and interpreted using a variety of evidence analytical techniques such as SWOT analysis, system analysis and root cause analysis or causal mapping where possible.

Classification	Definition
High	High relevance for the UK food and drink sector Good financial-economic decarbonisation data Recent information (after 2000) Provides a good example or story of decarbonisation Validated across all evidence gathering methods
Medium high	Relevance for the UK food and drink sector Financial-economic data not always complete or clear-cut and only generic decarbonisation data Provides a good example or story of decarbonisation Validated by more than one evidence gathering method
Medium low	Information that is too general or too specific Relevant grey literature Old information but still relevant Only mentioned via one evidence gathering method
Low	Background information No or low applicability for the UK food and drink sector Grey literature of limited value Old information Lack of relevance or only mentioned once

Table 9: Evidence classification definition

The following tables provide a summary of raw data collected relating to barriers and enablers.

3. Detailed Analysis of Enablers and Barriers

Enablers

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
1	**Investment**	**A strong, evidence-based business case for energy/carbon reduction that captures all benefits and cost.**	**3 sources:** 'Carbon Trust, 2008, Industrial Energy Efficiency Accelerator: Guide to the industrial bakery sector' - "*Business case – this will need to be robust, which means capturing all costs and financial savings (which must be deliverable). The sector would like to see all potential and knock-on benefits captured, e.g. could a carbon reduction measure also help increase productivity or reduce maintenance requirements?* "	**2 Interviews:** Head of Environment of a major drink manufacturer stated "Modern bottling production lines are much more compact than 20 years ago. They can be fitted in a smaller place, which reduces the need of conveyers, allows better monitoring and lowers the staff needed. All these benefits help us justify the 30% (0)reduction in energy use as only then the investment meets our internal requirements." A workshop attendee concluded that "clearly more benefits, especially such with direct economic	**Average: high impact** High impact – 58% (11) Medium impact - 26% (5) Limited impact – 16% (3) No impact – 0% (0) I don't know – 0% (0)	**Impact level: high** **Rationale:** An absolute necessity to get senior management to consider energy related projects, more so than for production or marketing projects. This is to a large extent driven by two factors: • High risk averseness of top management which leads to greater scrutiny; • Unattractive financials of energy efficiency compared to other projects	This is one of the key enablers according to survey and workshop participants. Capturing all costs and financial savings, can provide support to get executive buy-in and pursue more energy efficient technologies. Workshop participants described this enabler as an absolute necessity for senior management to even consider any energy related projects, more so than for product development or marketing projects. This is mostly driven by increased risk-averseness due to the weak economic climate and rising pressure from food and drink retailers to reduce cost. Workshop participants also concluded that a robust business case is often difficult to develop for break-through technologies as there is lack of reliable information about the savings potential and profitability of such technologies. This enabler is applicable now and will continue to grow in importance once the economic climate stabilises and new technologies are commercialised.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			'HMG, 2011 Enabling the Transition to a Green Economy: Government and business working together' – "*Benefits justify the costs, as well as providing a robust, credible and long-term policy framework to increase business certainty of payback from investment*." 'Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource Efficiency: Unlocking Cost Savings, Jobs and Environmental Improvements' – "*Robust and comprehensive business cases to*	impact on bottom-line results will help justify the cost."			

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			attract funding, expressed in the language of finance"				
2	**Management**	**Top management leadership and genuine commitment to make climate change a priority.**	**3 sources:** 'Heather Haydock (Ricardo-AEA) and Tamaryn Napp (Imperial College), Decarbonisation of heat in industry - A review of the research evidence' – "*A key organisational driver is the willingness of top management to make climate change a priority. This is crucial as it affects the overall culture of the firm.*" 'Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource Efficiency: Unlocking Cost	*2* **Interviews:** One workshop attendee concluded: *"It is very simple. Top management is under a lot of pressure to deliver short-term financial results. The only way to get energy efficiency projects past the investment criteria threshold and to compete with other projects internally, is if carbon reduction is a company priority and is owned at the highest level possible."* An interviewee concluded:: "*Our workforce (from the floor to management) is absolutely committed to our*	**Average impact: high** High impact – 58% (11) Medium impact - 21% (4) Limited impact – 21% (4) No impact – 0% (0) I don't know- 0% (0)	**Impact level: high** **Rationale:** "It is very simple. Top management is under a lot of pressure to deliver short-term financial results. The only way to get energy efficiency projects pass the investment criteria threshold and compete with other projects internally, is if carbon reduction is a company priority and is owned at the highest level possible. There are a lot of examples to support this: M&S "A Plan", Unilever's USLP. Both are part of	Senior management buy-in and formal business commitment plus increasing willingness of top management to make climate change a priority is supporting the prioritisation of a company's carbon strategy, compared to other aspects of the business strategy. This can create a ripple effect across the business and increase the importance of carbon reductions. Unilever's Sustainable Living Plan and M&S 'Plan A' were identified as success stories of such a leadership commitment from the UK food and drink sector. This enabler is applicable now.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			Savings, Jobs and Environmental Improvements' - *"CEO leadership and genuine commitment to resource efficiency is a key driver"* 'Oakdene Hollins, 2011, The Further Benefits of Business Resource Efficiency' - *"Organisational aspects, such as who has power to influence the culture and decision-making."*	*environmental targets. We have high level of recognition of the CSR program, including strong commitment from the top management and we communicate internally very regularly."*		how mainstream business is done and help the business become more resilient."	
3	**Management**	**Effective sharing of information and best practice within the organisation and across various departments/sites .**	**2 sources:** 'BPEX, 2011, ADVANCING TOGETHER A Roadmap for the English Pig Industry' – *"The enthusiastic engagement and active participation*	***2* Interviews:** A workshop attendee concluded: *"Case studies are a good way of increasing general awareness, as well as industry benchmarking which shows hard evidence*	**Average impact: medium** High impact – 37% (7) Medium impact - 53% (10) Limited impact – 11% (2) No impact – 0% (0) I don't know- 0%	**Impact level: high** **Rationale:** "Case studies are a good way of increasing general awareness, as well as industry benchmarking which shows hard	One challenge that companies, especially large multinationals, face is the effective exchange of best practice among production facilities and with the head office. As Dr. G. Lavery, 2014 rightfully suggests, this involves not only sharing what is done well at one site but also actively looking for what other plant managers are doing to reduce their carbon emissions and improve energy

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			of all those involved in the production process is a crucial factor" 'Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource Efficiency: Unlocking Cost Savings, Jobs and Environmental Improvements' - *"Staff taking responsibility for both disseminating and looking for good practice between sites/divisions"*	*on the benefits of innovations. The only issue with benchmarking is that it is hard to get companies to share certain information. The way of presenting environmental innovation to companies has a large effect on uptake as perceptions play a large part in investment."* Supply Chain Development Manager at EBLEX: *"EBLEX and Green Food (Newcastle Uni) are trying to set up a Central Knowledge Hub this perceived as very useful within this industry."*	(0)	evidence on the benefits of innovations. The only issue with benchmarking is that it is hard to get companies to share certain information. The way of presenting environmental innovation to companies has a large effect on uptake as perceptions play a large part in investment."	efficiency. Workshop attendees suggest that case studies work very well to capture best practice and increase awareness. This enabler is applicable now.
4	**Management**	**Proximity of the energy manager to the CEO in the corporate hierarchy.**	**1 source:** 'CSE, ECI, 2012, What are the factors influencing energy behaviour	**1 Interview:** Head of Sustainability: "A collaborative approach to support	**Average impact: medium** High impact – **21% (4)** Medium impact -	**Impact level: high** **Rationale:** "The issue with management in a	Decision-making for large investments is made at the highest level in the company; therefore if energy managers are able to influence these decisions by having access to the CEO and senior management then

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			and decision-making in the non-domestic sector?' – *"The closer that an energy manager is to the CEO in the corporate hierarchy the more likely that energy management activity will take place"*	implementation of new technology in regards to the funding, research and knowledge within the company helps if the energy manager works in close proximity to the CEO"	**32% (6)** Limited impact – **21% (4)** No impact – **11% (2)** I don't know- **16% (3)**	company is how the company dedicates itself to making decisions. The proximity of the decision maker is often subject to the company's priorities and also its size. Managers will always be interested in ideas that will save money, meet regulation or meet corporate objectives. A good corporate commitment is proven to lead to implementation on the ground. Publicity of issues such as energy efficiency will encourage managers to pay more attention to decision-making because publicity will cause	this influences energy behaviour and decision-making.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
						investors to alter their opinions on a company."	
5	**Supply Chain**	**Collaboration with the supply chain -offering practical information, demonstration of technologies and driving economies of scale.**	**4 sources:** 'AIC, 2012, Meeting the challenge: Greenhouse Gas Action Plan of the agriculture industry in England, progress report and phase II Delivery' – *"Collaboration with the supply chain - offering practical information and demonstration"* 'BPEX, 2011, ADVANCING TOGETHER A Roadmap for the English Pig Industry' – *"Close supply chain co-operation needs to be strengthened so that processors*	**3 Interviews:** Head of Sustainability for a major manufacturer stated "There is not integrated approach for the Food &Drink sector in the R&D area. We need more collaboration to support implementation, especially in terms of funding and R&D." A workshop attended concluded "Collaboration in our industry it is crucial, as it helps share the risk and speeds up innovation" Head of Sustainability: *"Work with retailers on knowledge transfer. (Retailers are mainly focused on Waste –*	**Average impact: low** High impact – **5% (1)** Medium impact - **16% (3)** Limited impact – **53% (10)** No impact – **16% (3)** I don't know- **11% (2)**	**Impact level: high** **Rationale:** "Collaboration in our industry it is crucial, as it helps share the risk and speeds up innovation"	The food and drink sector in the UK is quite diverse in terms of types of products and thus can be characterised by a fairly complex value chain. Retail chains have strong bargaining power over manufacturers and in turn manufacturers pass that pressure on raw material suppliers. Workshop attendees have expressed the concern that for retailers the key focus is cost reduction and not reducing environmental impacts, including carbon reduction. Yet, a product life-cycle approach has already been considered by the UK food and drink manufacturers and this will require stronger collaboration across the entire value chain in the future. This type of opportunity supports the overall need for greater consideration for collaboration across the value chain, to share the risks and speed up innovation. This enabler is relevant now and will become increasingly important in the future.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			and retailers are able to source secure supplies of the pigs they need" 'Best Foot Forward, 2012, Phase I synthesis report: Evidence to support the development of a sustainability roadmap for soft drinks' – *"Improved engagement across the supply chain – recommendations on how this could be achieved can be sought from the stakeholders themselves and the Project Management Group. Improved education of those working in the supply chain – to improve skills, including resource*	*zero to landfill, production waste reduction). Energy has been weak so far."*			

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			efficiency management" 'Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource Efficiency: Unlocking Cost Savings, Jobs and Environmental Improvements' – *"Collaborating along the supply chain to reduce resource use by looking for system solutions, creating lower impact products which better meet customer needs (including servicing), and driving scale. This includes optimising across the farm and manufacturing system."*				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
6	**Management**	**Realistic targets, KPIs and company norms/policies on energy savings and carbon reduction.**	**2 sources:** 'Carbon Trust, 2012, Food and drink processing: introducing energy saving opportunities for business' - *"Setting realistic targets for energy savings will help to keep the momentum going and to maintain employee awareness and interest. Set deadlines for the completion of each improvement detailed on the action plan and check to ensure that each has been completed."* 'Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource	***2 Interviews:*** Interviewee: *"Targets are really important in seeing and realising the direction the company is going. CCA/EU ETS is a really good policy – there is also an incentive to meet your target – discount on CCL)"* Sustainability Manager: *"Through Dairy UK, Dairy UK is aligned to the Milk Roadmap, and thus the targets are aligned which is beneficial for progress in the sector."* Head of Energy Procurement: *"We have a number of experts that look at how to optimise the core processes – using benchmarks*	**Average impact: medium** High impact – **37% (7)** Medium impact - 47% Limited impact – **16% (3)** No impact – **0% (0)** I don't know- **0% (0)**	**Impact level: high** **Rationale:** "It is important to have targets that are realistic and measurable in order for them to be managed. The question is how to use KPI's to drive performance, it is important to take note of KPI's that vary from the norm. Appropriate timescales to meet targets also need to be established. The issue with having targets for carbon reduction is getting companies to understand exactly what carbon means and how it can be reduced using targets – How can KPI's be translated to operating	Setting targets and establishing corporate and site-level KPIs with regards to reducing carbon emissions and energy consumption are perceived as key to keep the momentum and mobilise the workforce. When such commitments are made public that allows companies to exert certain influence over suppliers and customers and engage them on the journey to achieving these targets. As a result workshop participants perceive commitments as the first step to embedding carbon reduction and energy efficiency in the strategic agenda of the business and making sure everyone in the business from the production floor to the Board of Director is doing something to achieve these commitments. These targets need to be realistic and time-bound to allow the business to adapt but stretching enough to provide direction and nurture an innovation-driven culture. This enabler is applicable now.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			Efficiency: Unlocking Cost Savings, Jobs and Environmental Improvements' – *"Management execution of resource efficiency assisted by KPIs, company values/norms, and expert knowledge (e.g. provided by Head of Sustainability)."*	*with other European manufacturers and speaking to equipment manufacturers."*		processes. In the F&D industry many of the sub sectors have signed up to climate change agreements that allow certain energy-intensive subsectors to receive up to 90% (0)reduction in the climate change levy. This is only allowed if they sign up to stretching energy efficiency targets agreed with the government. Problems with data collection for targets is that companies can be burdened with too much data, for it to be useful for setting targets the data collection needs to be more focused."	
7	**Investment**	**Projects providing**	**3 sources**	**2 Interviews:**	**Average impact: high**	**Impact level: medium**	To cope with the rising pressure to reduce production cost and improve

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
		multiple benefits (energy & labour cost reduction, improved productivity, product quality, etc.).	'CSE, ECI, 2012, What are the factors influencing energy behaviours and decision-making in the non-domestic sector' – *"The most successful projects joined up different kinds of low-carbon behaviours (energy, waste, transport etc)"* 'Carbon Trust,2011, Industrial Energy Efficiency Accelerator - Guide to the confectionery stoving sector' – *"Most sites work at or near full capacity and stoves operate 24 hours a day, seven days a week. Whilst manufacturers*	Head of Energy Procurement: *"Most projects don't pay so we work with manufacturers to get the cost down to be viable for us to invest – customise the technology to meet British sugar requirements and maximise their benefits, more cost effective."* Head of Environment of a major drink manufacturer stated *"Modern bottling production lines are much more compact than 20 years ago. They can be fitted in a smaller place, which reduces the need of conveyers, allows better monitoring and lowers the staff needed. All these benefits help us justify the 30% (0)reduction*	High impact – 90% (17)) Medium impact - **5% (1)** Limited impact – **5% (1)** No impact – **0% (0)** I don't know- **0% (0)**	**Rationale:** "Clearly more benefits, especially such with direct economic impact on bottom-line results will help justify the cost. However, it is important to differentiate that for small companies, especially, such multi-benefit solutions (e.g. robots) can be very expensive. Thus upfront cost is prohibitive and will remain so in the near future."	profitability margins, managers in the food and drink sector favour projects that can not only help reduce energy and associate cost with it, but also increase the productivity, reduce labour cost and achieve overall process optimisation. As explained by workshop participants, this stems from the fact that energy is not perceived as priority in many business due to the low percentage that energy cost contributes to total production cost (2-15%). This enabler is applicable now.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			have considered expanding their operations, the high capital associated with installing additional stoves has in part deterred this. All manufacturers have experimented with alternative stoving technologies – notably heat pumps – in a bid to reduce production cycle times, and they remain interested in ways to reduce stoving cycle times and increase production capacity. Shorter production cycle times will reduce energy consumption accordingly." 'Carbon Trust,	*in energy use as only then the investment meets our internal requirements."*			

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			2005, The UK Climate Change Programme: Potential evolution for business and the public sector' – *"Other financial co-benefits or co-costs of new equipment (e.g. improved control, etc.)"*				
8	**Market**	**Industry driven long-term targets, roadmaps and initiatives on carbon reduction and energy efficiency.**	**3 sources** 'B. Sturm, Opportunities and barriers for efficient energy use in a medium-sized brewery' – "*The AIC negotiates the CCA with Defra and provides a forum for the industry to discuss environmental issues. This gives it an important position in driving the carbon reduction agenda*	**1 Interview:** One workshop attendee concluded: *"It is very simple. Top management is under a lot of pressure to deliver short-term financial results. The only way to get energy efficiency projects past the investment criteria threshold and to compete with other projects internally is if carbon reduction is a company priority and is owned at the highest level possible."*	**Average impact: medium** High impact – **21% (4)** Medium impact - **42% (8)** Limited impact – **37% (7)** No impact – **0% (0)** I don't know- **0% (0)**	**Impact level: medium** **Rationale:** "It is definitely a driver. Industry wide commitments help create awareness among top management and establish balance between short-term and long-term focus of the business- driving more aspirational agendas."	Industry driven targets, roadmaps and initiatives on carbon reduction and energy efficiency are important to move away from short term business thinking. Industry need to make these targets high on the agenda of the business, this will drive progress now and benefit the future.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			within the industry” ‘FDF, 2008, Refrigeration Energy Efficiency initiatives’ – *“Improved sharing of best practice – building on and sharing good work in the sector through channels and consortia already implemented”* ‘FDF, 2013, Food & Drink Manufacturing The UK’s largest manufacturing industry: delivering sustainable growth through innovation’ – *“The Five-fold Environmental Ambition has been a motivating factor to help us minimise our environmental impacts. ”*				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
9	**Operations**	**Including energy efficiency in the design processes for new products, packaging and distribution systems.**	**1 source:** 'Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource Efficiency: Unlocking Cost Savings, Jobs and Environmental Improvements' – *"Including resource efficiency in design processes including for new production processes, products, packaging and distribution systems. This includes design for reuse, remanufacture, recycling, and inclusion of bio-based and recycled materials in products and packaging"*	**2 Interviews:** Sustainability Manager: ***"****Process control and simulation to match energy consumption to what is needed and reduce energy and waste through automation and sensors. - Production lines are linear in nature – so why not design the process so it is close to where energy/heat is needed – especially about temperature changes – heating and cooling."* Manager: *"Production lines are linear in nature – so why not design the process so it is close to where energy/heat is needed – especially about temperature changes – heating and cooling."*	**Average impact: medium** High impact – **42% (8)** Medium impact - **37% (7)** Limited impact – 16 % No impact – **5% (1)** I don't know- **0% (0)**	**Impact level: medium** **Rationale:** "The group agreed that energy efficient design should be in the upfront of any project. Policy can be an important contributing factors here, if incentives/permits are given primarily for showing that you take BAT into account and not only focus on the end-consumer."	There are a number of ways in which energy efficiency can be implemented into the design process of products, packaging and distribution systems. This knowledge needs to be implemented and best practice shared with industry.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
10	**Regulation**	**Compliance to environmental and carbon specific regulations (CCL, EU ETS, R22, F-gas) and participation in voluntary agreements (such as CCA).**	**11 sources** 'Dairy Supply Chain Forum's Sustainable Consumption & Production Taskforce,2008, The Milk roadmap' – *"Environmental regulations are driving changes in practice. Proposed changes to the Nitrates Action Plan, the Water Framework Directive and Climate Change and air quality legislation impact on the dairy sector"* 'Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the animal feed milling sector' – *"But it's questionable how significant the CCA*	**2 Interviews:** Sustainability Manager: *"Mandatory energy audits and complying with these could be a strong driver of energy efficiency."* *Environment Director: "At a macro level – global Climate Change policies are what we are concerned about, as in longer term compliance to these is what is needed to ensure our place in the future".*	**Average impact: medium** High impact – **37% (7)** Medium impact - 48% (9) Limited impact – **11% (2)** No impact – **5% (1)** I don't know- **0% (0)**	**Impact level: medium** **Rationale:** "Currently, the regulatory framework allows companies to buy their way out – e.g. EU ETS – if companies emit more emissions than allowed, they can easily buy extra permits. Policy incentives should be more linked to implementation of energy saving opportunities and taking actions. "	Compliance to environmental regulation is already a norm in the UK food and drink sector as manufacturers cannot afford to jeopardise their reputation and brand value, as well as the unnecessary cost in the form of fines. Several workshop attendees highlighted the fact that their commitments with regards to the Climate Change Agreements as well as the EU ETS have been key drivers to reducing CO_2 emissions from manufacturing. The volatile energy prices, insecurity of energy supply and low price of carbon, coupled with the long-term uncertainty around legislative direction, can transform this enabler into a barrier if incentives are reduced or the bureaucratic burden increases. Thus, this enabler is relevant now and will become increasingly important in the future.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			is as a direct driver for energy efficiency at a site level, because the targets apply to the whole sector rather than individual companies. Also, the cost of carbon, as measured by the CCL, is relatively low in comparison with the value of energy" 'Carbon Trust, 2008, Industrial Energy Efficiency Accelerator: Guide to the industrial bakery sector' – "Impact of carbon legislation - The Climate Change Levy (CCL) is charged on non-domestic energy bills for both electricity and selected fossil				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			fuels, including natural gas. Industrial bakeries can receive a rebate on the Levy if they have a CCA with associated energy performance targets, and this financial benefit is a significant driver” Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the dairy sector’ – *“Regulatory compliance (EU ETS, CCA, etc.)”* Carbon Trust, 2011, Industrial Energy Efficiency Accelerator - Guide to the maltings sector’ – “Regulation (EY ETS, CCA, CLA)”				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			Carbon Trust, 2011 Industrial Energy Efficiency Accelerator - Guide to the brewing sector' – "*Regulatory drivers- Climate Change Agreement - The UK brewery sector is covered by a Climate Change Agreement, under which its members receive an 80% (0)(65% from April 2011) discount on the Climate Change Levy, which is a surcharge on energy bills. EU Emissions Trading Scheme/ F-Gas Regulations/ Ozone depleting substance regulations (R22 phase out)/ IPPC*"				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			Carbon Trust, 2012, Food and drink processing: introducing energy saving opportunities for business' – "*Around a quarter of the sites also indicated that they were considering a new plant installation in the near future, driven mainly by the need to replace their R22 refrigeration systems*" Russell C. McKenna, 2009, Industrial energy efficiency Interdisciplinary perspectives on the thermodynamic, technical and economic constraints' – *"The two main drivers*				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			behind the adoption of energy efficiency measures in industry are costs and legislation" 'Carbon Trust,2011, Industrial Energy Efficiency Accelerator - Guide to the confectionery stoving sector' – *"Legislation impacts - The major energy-related legislation for this sector is the Climate Change Levy and the associated Climate Change Agreements, which most of the manufacturers hold though the food and drink Federation"*				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			'BPEX, 2011, ADVANCING TOGETHER A Roadmap for the English Pig Industry' – "*Continued participation in the Climate Change Levy Rebate Scheme (CCL), and requirements of EPR Permits are drivers for change along with minimising the impact of energy inflation*" FDF, 2008, Refrigeration Energy Efficiency Initiative' – "*Legislation(R22,F Gases)*"				
11	**Management**	**Specific circumstances such as relocation, merger, change of leadership.**	**1 source:** 'CSE, ECI, 2012, What are the factors influencing energy behaviours and decision-	**1 Interview:** Environment Director: "We are already squeezing the most we can from our plants	**Average impact: limited** High impact – **5% (1)** Medium impact - **26% (5)**	**Impact level: medium** **Rationale:** "Such circumstances play a pivotal role,	Often there is not the opportunity for big changes to be made in Business As Usual. When there is a large change of circumstances in a company such as relocating, merging or change of leadership, this time of change is often the driver for

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			making in the non-domestic sector?' – *"Specific circumstances can offer unique opportunities for change (e.g. relocation; merger; major investment; change of leadership)."*	space. Therefore we need more space, which movement or restructure would offer – we could then tie this in with development of plants."	Limited impact – **21% (4)** No impact – **32% (6)** I don't know- **16% (3)**	sometimes, as they allow the production process to shut-down and install new equipment or repair current one. In any other case, management is very reluctant to halt production"	development as opportunities open for new ideas/technology.
12	**Market**	**Consumer pressure on producers to demonstrate carbon reduction in the supply chain. (CSR)**	**6 sources:** Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the animal feed milling sector' – *"Changing customer demand - Consumers and major retailers are starting to demand information on embedded carbon in consumer goods. This is driving farmers to reduce the carbon footprint of animal products.*"	**1 Interview:** Sustainability Manager: *"Customers are looking more for 'modern' bottles and packaging that are lighter and less carbon intensive."*	**Average impact: limited** High impact – **11% (2)** Medium impact - **32% (6)** Limited impact – **21% (4)** No impact – **37% (7)** I don't know- **0% (0)**	**Impact level: medium** **Rationale:** "Inconsistent messages from consumer/customers. Very often when manufacturers increase their emissions, they save emissions elsewhere in the product lifecycle and thus reduce overall emissions per product. Another challenge is the scope of	Customer demand is changing slowly. They are looking for packaging that is easy to recycle, light and low carbon. Saving emissions in one stage of the life cycle often means increased emissions at a later stage, often these become out of scope for reporting so customers get mixed messages.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			Carbon Trust, 2008, Industrial Energy Efficiency Accelerator: Guide to the industrial bakery sector' – *"Corporate responsibility is also a key driver for carbon reduction, driven by key stakeholders: retailers and consumers."* Carbon Trust, 2011, Industrial Energy Efficiency Accelerator - Guide to the maltings sector' – "CSR & sustainability" Carbon Trust, 2011 Industrial Energy Efficiency Accelerator - Guide to the			measurement as currently requirements differ significantly."	

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			brewing sector' – *"corporate responsibility -for example, by setting voluntary carbon reduction targets; producing product carbon footprints; or investing in environmental initiatives which reduce energy use and carbon emissions"* The UK Government's Business Taskforce on Sustainable Consumption and Production, 2008, Decentralised Energy: business opportunity in resource efficiency and carbon management' – *"Widespread operations at a*				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			range of scales with a significant over all carbon footprint – growing consumer pressure to account for carbon in the supply chain – potential product or brand differentiator" FDF, 2008, Refrigeration Energy Efficiency Initiative' – *"Consumers diets and purchasing habits"*				
13	**Market**	**Support and innovative schemes by customers (retailers) for delivering product enhanced environmental and carbon performance.**	**3 sources:** 'Dairy Supply Chain Forum's Sustainable Consumption & Production Taskforce,2008, The Milk roadmap ' - *"Responding to consumer demand through retailer-led initiatives: For*	**1 Interview:** Group Sustainability Manager: *"We have been working with a top retailer who has been very demanding in regards to helping farmers reduce their emissions which has been positive."*	**Average impact: limited** High impact – **5% (1)** Medium impact - **37% (7)** Limited impact – **42% (8)** No impact – **16% (3)** I don't know- **0% (0)**	**Impact level: limited** **Rationale:** "It is important to differentiate here between key and small customers. Such schemes are crucial where business is depended on key	Retailers have influence over the manufacturing process of the products they buy due to industry knowledge and connections. They can aid manufactures reduce their emissions. Therefore this relationship should be used more to enhance product environmental performance.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			example, a number of retailers now offer their producers a premium price for delivering consumer identifiable benefits, which may include enhanced environmental performance." Carbon Trust, 2011, Industrial Energy Efficiency Accelerator - Guide to the maltings sector' – "*customer carbon footprinting programmes*" EBLEX, 2012, Down to Earth - the beef and sheep roadmap - phase three' – "*Retailers support and innovative*			retailers. In reality retailers offer such schemes only to their key suppliers. Nevertheless, carbon reduction is not a top priority of retailers – lower price is."	

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			schemes"				
14	**Operations**	**Production site level energy audits, which identify inefficiencies and leaks.**	**2 sources:** Best Foot Forward, 2012, Phase I synthesis report: Evidence to support the development of a sustainability roadmap for soft drinks' – *"Increase and implement production site level audits to identify inefficiencies and leaks"* Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource Efficiency: Unlocking Cost Savings, Jobs and Environmental Improvements' – *"Understanding the production system*	**1 Interview:** Energy Manager: *"Mandatory energy audits could be a strong driver of energy efficiency"*	**Average impact: medium** High impact – **58% (11)** Medium impact - **32% (6)** Limited impact – **11% (2)** No impact – **0% (0)** I don't know- **0% (0)**	**Impact level: limited** **Rationale:** "Within the current set-up energy audits have limited impact as they do not require follow-up and corrective actions. The impact of the enabler will increase if audits become more enforcing."	Energy audits are important in identifying inefficiencies however these needs to be followed up regularly to ensure findings are dealt with and improvements are made.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			– knowing where it is best to act on a meta level and how single organisations can act within the system to support progress"				
15	**Innovation**	**Investment support and low-interest financing (e.g. GIB) for R&D activities and knowledge transfer in the industry.**	**4 sources:** Dairy Supply Chain Forum's Sustainable Consumption & Production Taskforce,2008, The Milk roadmap' - *"Technology, Research and Development is critically important in improving the competitiveness and environmental performance of the UK dairy industry and its role cannot be underestimated. It is essential that funding and time*	***1 Interview:*** Head of Sustainability for a major manufacturer stated *"There is not an integrated approach for the Food & Drink sector in the R&D area. We need more collaboration to support implementation, especially in terms of funding and R&D."*	**Average impact: medium** High impact – **32% (6)** Medium impact - **26% (5)** Limited impact – **21% (4)** No impact – **21% (4)** I don't know- **0% (0)**	**Impact level: no** **Rationale:** **"**Funding is not an issue. Challenge is to get past the internal investment threshold and win over other internal projects."	Investment is essential for R&D and support is needed via low-interest financing, grants and funding. Collaboration is also important. This will allow new technologies to be introduced to the food and drinks industry which can aid in cutting emissions.

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			continues to be invested to ensure that British dairy farmers are well placed to take advantage of new technologies and advances in breeding, feeding and other environmentally and economically beneficial areas. This must be achieved not only through the industry levy body, but through continued Government investment in research that challenges current husbandry best practice; an area which has great potential for improved environmental performance.”				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			HMG, 2011 Enabling the Transition to a Green Economy: Government and business working together' – *"Funding support will remain necessary and important, especially for technological innovations"* BPEX, 2011, ADVANCING TOGETHER A Roadmap for the English Pig Industry' – " *the continued investment in Research & Development into the key areas of feed, meat yield and waste management"* FDF, 2012, VISION FOR INNOVATION IN				

#	Category	Enablers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			FOOD AND DRINK MANUFACTURIN G' – *"The Food Industry urgently requires support to stimulate and facilitate R&D activities and knowledge transfer to help meet the Government priorities and to ensure it remains a viable and sustainable national industry, and a significant innovator in competition with other EU and international states."*				

Table 10: Enablers

Barriers

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
1	Investment	Long investment cycles (due to equipment lifespan) and high capital/upfront costs of new technologies.	8 sources: Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the animal feed milling sector' – "*It is always challenging for businesses to justify the initial cost of metering as the installation itself does not lead directly to savings"* Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the dairy sector' – "*Cost of new equipment and process reconfiguration; pricing likely to be attractive when existing equipment is replaced"* CSE, ECI, 2012, What are the factors influencing energy	2 interviews: One interviewee stated that *"I only have the opportunity to make big changes [to plant] if new lines are brought in or there is production down time. Otherwise, I cannot justify financially the disruption of production cycle and the opportunity cost."* Manager: *"If equipment is nearly broken or end of life, companies will invest to carry on productions."*	Average impact: medium High impact – 47% (9) Medium impact – 32% (6) Limited impact – 21% (4) No impact – 0% (0) I don't know – 0% (0)	Impact level: high Rationale: "It is very important barrier but very often it is just a convenient perception to avoid extra work where possible. In other cases, it is driven by lack of reliable input to make a decision upon or access to such advice."	The sector investment cycles are to a large extent dictated by the lifespan of manufacturing equipment, which can often be as long as 40 years. This in itself presents very few opportunities to upgrade the entire production line and achieve major energy and carbon savings until 2050 - there will only be one or at most two investment cycles, depending on the company. Additionally, high upfront cost of such investments often limits the financial ability of UK food and drink manufacturers to upgrade multiple production lines at the same time. Rather, companies take gradual approach to upgrading their plants' equipment. SMEs in particular, find the upfront cost of advanced technologies such as robotics prohibitively expensive. This is a barrier now and will remain so in the future.

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			behaviours and decision-making in the non-domestic sector?' – "*Upfront costs are cited as a significant disincentive.*" DECC: The Future of Heating: Meeting the challenge' – *"Investment cycles and capital costs: Investment in new more efficient plant requires major investment, and is unlikely to be possible outside normal investment cycles, which can sometimes be 40 years or longer. Also returns from energy efficiency investment are low and can be uncertain, and in many companies, bids for investment will compete at a global level against spend on process and products"*				

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			Carbon Trust,2011, Industrial Energy Efficiency Accelerator - Guide to the confectionery stoving sector' –"*High capital value is a significant challenge"* The UK Government's Business Taskforce on Sustainable Consumption and Production, 2008, Decentralised Energy: business opportunity in resource efficiency and carbon management' – *"Cost and long payback – within the food industry there is a tendency for long payback periods for investment that is not core business*" McKinsey & Co, 2009, pathways to low-carbon economy, version 2 of the Global Greenhouse Gas				

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			Abatement Cost Curve' – *"Financing hurdles and rapid payback requirements: the upfront investment itself can be a significant barrier"* B. Sturm, Opportunities and barriers for efficient energy use in a medium-sized brewery '- *"One of the key challenges is high capital expenditures, prioritisation of investment"*				
2	Investment	Limited access to funds (or needed for other priorities) and high cost of external capital.	11 sources: Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the dairy sector' – *"Availability of funds to support research, and potential concerns about confidentiality."* Carbon Trust, 2011 Industrial Energy Efficiency Accelerator	2 Interviews: *'The Milk roadmap'* - *"Technology, Research and Development is critically important in improving the competitiveness and environmental performance. It is*	Average impact: medium High impact – 47% (9) Medium impact – 32% (6) Limited impact – 21% (4) No impact – 11% (2) I don't know – 0% (0)	Impact level: high Rationale: "The bad economic climate in recent years, one-year contracts with customers and existing overcapacity in some subsectors have led to low	Lack of resources deployed to identifying available funding, and the reluctance to move to third party financing are seen as additional barriers to finding financing. Workshop attendees also indicated that there is a lack of collaboration on financing demonstration projects as this is seen as a competitive advantage and thus sharing the financial burden amongst manufacturers is limited. Large multinational companies expressed concern

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			- Guide to the brewing sector' – *"Available capital: Lack of available capital resources has been cited as a reason why breweries do not take up utility saving technologies. For example, modernising a brewhouse or replacing packaging equipment could be a multimillion pound investment which may not be justifiable on utility savings alone."* Heather Haydock (Ricardo-AEA) and Tamaryn Napp (Imperial College), Decarbonisation of heat in industry - A review of the research evidence' – "*Lack of resources, both in terms of time and capital, are considered to be major barriers by many firms."*	*essential that funding and time continues. Not only through the industry levy body, but through continued Government investment in research that challenges current best practice;"* *Energy Procurement Manager: "Cash is not available across the sector in general and long-term plans are very difficult to make."*		desire to invest. Priorities under these circumstances are on product and process quality. This limits the internal access to funds or interest to seek funds outside."	that energy reduction projects often compete with core business capex and product innovation projects overseas and longer payback times do not help secure that funding as risk is seen as too high. Workshop participants concluded that establishing a long-term regulatory framework will play an important role in reducing that perceived risk in the future. This is a barrier now and will remain so in the future.

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			CSE, ECI, 2012, What are the factors influencing energy behaviours and decision-making in the non-domestic sector?' – *"Access to capital is considered a key barrier for efficiency investment particularly for smaller organisations. However, some studies argue that when energy efficiency is reconfigured as having strategic value, access to finance becomes easier – particularly in larger organisations."* Russell C. McKenna, 2009, Industrial energy efficiency Interdisciplinary perspectives on the thermodynamic, technical and economic constraints' – *"Securing finance: CHP represents a*				

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			large capital investment compared to installing boilers and importing electricity from the grid. CHP's energy savings, and revenue from selling surplus electricity, decrease net operating costs. However, these savings may not be sufficient to meet rates of return ('hurdle rates') required to secure finance" BIS, 2010, Manufacturing in the UK: An economic analysis of the sector' – *"A key challenge is Access to capital"* Carbon Trust, 2005, The UK Climate Change Programme: Potential evolution for business and the public sector' – *"Percentage of firms reporting availability*				

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			and cost of finance as an important or very important constraint to innovation: 31% and 39% respectively" University of Sussex, 5.0 Barriers to energy efficiency in Brewing' – *"Access to capital: From the perspective of survey respondents and case study interviewees, limited access to capital provides one of the biggest barriers to energy efficiency. There are two possible explanations for this. First, the firm may be reluctant to borrow as this would increase the level of gearing, thereby increasing risk and raising the firm's cost of capital."* Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource Efficiency:				

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			Unlocking Cost Savings, Jobs and Environmental Improvements' – "*There is limited access to external funding for projects*" Hans Even Helgerud, 2009, Energy efficiency in the food and drink industry – the road to Benchmarks of Excellence' – *"Lack of investment capital or capital needed for other priorities"*				
3	Investment	Short term thinking and risk-aversion (especially if not proven) with regards to energy reduction projects.	3 sources: DECC: The Future of Heating: Meeting the challenge' – "*Short term thinking and risk: Conversely, many businesses focus decisions on the short to medium term rather than the longer term. Heat intensive industries are also risk-averse, and*	*1 Interviews:* *Energy Procurement Manager: "We need a change in approach in investment in energy reduction – we need build understanding internally to accept lower*	Average impact: medium High impact – 16% (3) Medium impact – 37% (7) Limited impact – 32% (6) No impact – 16% (3) I don't know – 0% (0)	Impact level: high Rationale: "Mostly driven by concerns over brand, short-term scope of the contracts with retailers and short term expectations of investors."	Short term thinking is practically present when investing, short ROIs are sought after but not viable for this technology. If technology is not proven then companies are very reluctant to invest in them as they are very risk averse just after the recession.

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			particularly wary of risks to their product quality or output, and of being locked-in to inflexible infrastructure and technologies" Russell C. McKenna, 2009, Industrial energy efficiency Interdisciplinary perspectives on the thermodynamic, technical and economic constraints' – *"Low risk approach: naturally, companies want to minimise risk, and this applies when it comes to the reliability of process plant and the quality of product. New equipment/design carries with it an unknown quantity in terms of reliability, and hence is viewed as a risk. The potential rewards have to be very high to make the perceived risk*	*returns on the basis of sustainability of the business." "We are a very risk averse business. There is no guarantee of what rate you will get from renewables and thus difficult to justify projects."*			

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			worthwhile" Oakdene Hollins, 2011, The Further Benefits of Business Resource Efficiency' – *"Loss aversion where individuals overweight the upfront costs relative to the long run benefits of investment"*				
4	Market	Risk of diminishing product quality, changing product character and consistency or eroding brand equity.	6 sources: Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the animal feed milling sector' - "*There is a very slow turnover of equipment in the animal feed sector. New technologies present a risk to product quality and output and need to be proven both to minimise this risk and also to demonstrate energy savings that justify the capital cost."* Carbon Trust, 2008,	1 Interviews: SHE Manager: *"Product quality and safety – you cannot compromise on these; even on a perception level. E.g. trial work on heat recovery in bread ovens, people asked first what impact it will have on the product; So decisions and discussion how to optimise product quality*	Average impact: limited High impact – 21% (4) Medium impact – 16% (3) Limited impact – 37% (7) No impact – 27% I don't know – 0% (0)	Impact level: high Rationale: "One of the strongest assets of the industry is branding and product quality. If any of these is compromised, companies may lose their position on the market or go out of business. In some cases, there are very strong regulatory	It is very unlikely for a UK food and drink manufacturer to invest in and implement a technology that may compromise product quality or change product character and texture, so that it may differ from the product specifications. This is can be explained by the fact that brand constitutes a price premium in the sector and any unwanted change to the product may erode brand and economic value. Thus the sector perceives unproven technologies as unnecessary business risk. subsector specific regulation maintain the high impact of this barrier. In the Spirits subsector for example, the whisky character is regulated by

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			Industrial Energy Efficiency Accelerator: Guide to the industrial bakery sector' – *"Product quality – if an innovation could affect product quality then this would be a key barrier. Innovations would need to have a proven track record to gain credibility with the sector"* Carbon Trust, 2011, Industrial Energy Efficiency Accelerator - Guide to the maltings sector' – *"..these concerns are mostly over product quality concerns, technical viability (open cycle heat pumps)"* Carbon Trust, 2011 Industrial Energy Efficiency Accelerator - Guide to the brewing sector' – *"Changing traditional brewing methods: Tradition has*	*and make process more efficient (Food Standard Agency) - food refrigeration, packaging, pasteurisation, so on."* One workshop attendee *concluded: "One of the strongest assets of the industry is branding and product quality. If any of these is compromised, companies may lose their position on the market or get out of business. In some cases, there are very strong regulatory requirements on production process and/or product*		requirements on production process and/or product specifications and thus these cannot be changed"	law and thus distillers cannot deviate from the prescribed production process. As a result, producers are limited in their choice of opportunities for technology improvement or new build. This is a barrier now and will remain so in the future.

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			been a very strong influence in how beer is made with many sites taking pride in producing beer in a similar manor for many years. Opportunities that involve changing this tried and tested method raise concerns that the reputation for consistency may be damaged, leading to loss of confidence in the brand" Carbon Trust,2011, Industrial Energy Efficiency Accelerator - Guide to the confectionery stoving sector' - "*Product quality- The quality and texture of the sweets is intrinsically associated with the product brands. Therefore, manufacturers are nervous about introducing any process changes that*	*specifications and thus these cannot be changed."*			

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			might change these." FDF, 2008, Refrigeration Energy Efficiency Initiative' – "*Possible Impact on beer flavour and quality*"				
5	Operations	Risk of production disruption, faulty installation and low reliability of new technologies.	4 sources: Heather Haydock (Ricardo-AEA) and Tamaryn Napp (Imperial College), Decarbonisation of heat in industry - A review of the research evidence' – *"Another important barrier to the adoption of low carbon and energy efficient technologies is the risk of disruption to production. Continuity of production is of primary importance to firms. This is one of the reasons that energy efficiency technologies tend to have more stringent economic criteria compared to*	*1 Interview:* Sustainability Manager: *"Timing is a real pain when implementing new technologies as there is a risk of delays in production and a risk of reducing the quality of the product. Complaints from customers are also a risk in change such as this as brand value is very important. "*	Average impact: limited High impact – 21% (4) Medium impact – 16% (3) Limited impact – 42% (8) No impact – 21% (4) I don't know – 0% (0)	Impact level: high Rationale: "Production is fundamental to running business, hence risks are unacceptable. Retrofitting means downtime of the production process, but it is often very difficult to interrupt the production process because companies have no stock or risk turning bad their fresh	The potential impact of any changes in operations on machine operability and disruption of production is a barrier to decarbonisation. Most of the manufacturing in the sector is on a non-stop basis. Production lines' downtime is carefully planned and reduced to absolute minimum. This is driven by constant and increasing pressure to maintain profitability margins and reduce cost. Thus the sector perceives lines upgrades and retrofits as risky unless near the end of the lifespan of the equipment. An additional factor that reinforces this barrier is the lack of proven and commercially tested technologies, which makes management reluctant to implement even if in downtime as this may cause disruptions and

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			investments that are more closely related to the core business" CSE, ECI, 2012, What are the factors influencing energy behaviours and decision-making in the non-domestic sector?' – "*There is unwillingness to replace equipment before end-of-life to avoid halting production and losing sales."* Carbon Trust,2011, Industrial Energy Efficiency Accelerator - Guide to the confectionery stoving sector' – *"Stoves are used intensively and considered to be reliable. Therefore, any technological or process alteration which may run the risk of reduced reliability will be a deterrent to*			feedstock. If technology supplier could take the risk, this could help overcome the barrier. But of course suppliers will only take limited risks and responsibility, certainly not on production losses. If standards are the same for everybody, a level playing field for BAT in energy efficiency would be created. An example of third party financing: Siemens performance contracting: projects financed by Siemens,	operational challenges in the future. This is a barrier now and will remain so in the future.

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			change" University of Sussex, 5.0 Barriers to energy efficiency in Brewing' – "*Technical risk may also be important for some technologies if there is any potential threat to equipment reliability"*			putting less risk at companies."	
6	Organisation	Shortage of qualified engineers and specialist skills and knowledge (especially in SMEs)	9 sources: Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the animal feed milling sector' – "*Advanced process optimisation requires an even greater level of skill and experience in energy management, coupled with the time to analyse complex interrelationships in the data"* Carbon Trust, 2011, Industrial Energy Efficiency Accelerator - Guide to the maltings	2 Interviews: One workshop attendee conclude that: *"… this is a very big barrier for the industry. Currently, companies are facing the challenge of not being able to recruit engineering graduates into food and drink manufacturing."* Group Sustainability	Average impact: limited High impact – 21% (4) Medium impact – 26% (5) Limited impact – 37% (7) No impact – 11% (2) I don't know – 5% (1)	Impact level: high Rationale: "Very big barrier for the industry. Currently, companies are facing the challenge of not being able to recruit engineering graduates into food and drink manufacturing. On the other hand, internally, engineers are currently not measured on	A shortage of technically competent staff, and a lack of funding for training prevent further advancement of the UK food and drink sector. A further challenge to the sector is attracting new recruits and talent. In particular, the sector's demand for engineers who understand the technical aspects of the industry that support energy efficiency implementation, such as heat engineers, is increasing. On the other hand, internally, engineers are currently not appraised adequately and not perceived as a key resource. There is a need to change outsider's perception of the industry and to invest in industry training and increase its availability to graduates and

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			sector' – *"Knowledge/skills (statistical management of inputs)"* CSE, ECI, 2012, What are the factors influencing energy behaviours and decision-making in the non-domestic sector?' – *"Lack of internal skills to interpret technical information and the time and capacity to plan energy management is a major barrier for smaller SME's"* DECC: The Future of Heating: Meeting the challenge' – *"Skills: The transition to low carbon industrial heat will require specialised, highly skilled and experienced heat focused engineers. These skills are not*	Manager: *"Greatest barrier is engineering resource to implementation – often need to buy temporary resources"*		energy efficiency and thus not perceived as priority. There is a need to change outsider's perception of the industry. There is also a need for companies to invest in industry training and increase its availability to graduates and other professionals. There needs to be actions to create incentives for companies to have graduate training schemes. Without any skills many companies in the industry will	other professionals. This is a particular barrier now as the profile of the workforce of the sector is ageing without sufficient succession planning in place.

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			readily available in the industry.” Russell C. McKenna, 2009, Industrial energy efficiency Interdisciplinary perspectives on the thermodynamic, technical and economic constraints’ – “*Lack of staff/de-skilling of work force: there is a trend towards reducing the numbers of professional staff employed within UK companies. Those that are left have increasing workloads and tend to be less qualified. This has the result that staff have little time to support/develop new projects and may not have the technical know-how.*” BIS, 2010, Manufacturing in the			be dead in the water, software engineers are needed to drive factories and develop simulated production techniques.”	

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			UK: An economic analysis of the sector' – *"Some firms, particularly small and medium sized enterprises (SMEs), may experience difficulties accessing knowledge of the latest industrial ideas, technologies and practices or finding professional support and advice on how these can be applied to their business. For example, in manufacturing there is evidence to suggest that many manufacturing firms are not aware of the economic and financial benefits of greater automation"* Best Foot Forward, 2012, Phase I synthesis report: Evidence to support the development of a sustainability roadmap				

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			for soft drinks' - *"Lack of knowledge or ability to improve skills to identify and/or implement reduction opportunities 'on the shop/production floor'"* Dr Greg Lavery, 2014, Food and Beverage sector Non-Labour Resource Efficiency: Unlocking Cost Savings, Jobs and Environmental Improvements' – *"Skills – there is a shortage of engineers and it is difficult for SMEs to access specialist skills"* The UK Government's Business Taskforce on Sustainable Consumption and Production, 2008, Decentralised Energy: business opportunity in resource efficiency and carbon management' – *"The*				

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			technology-skills gap in supply and maintenance of equipment and downsizing the equipment for smaller operators n Perceived higher risks relating to the technology and the cost or price of energy"				
7	Innovation	Shortage of proven and demonstrated energy-efficiency technologies.	4 sources: Carbon Trust, 2008, Industrial Energy Efficiency Accelerator: Guide to the industrial bakery sector' – "*Proven technology – the sector has previously implemented innovations, most notably heat recovery on ovens. However, because a number of test applications have failed, there are concerns about the potential to deliver proven solutions with the longevity to*	2 Interviews: Energy Manager: *"There is so much drive at the moment on innovation to meet the market requirements and consumer requirements – snacking, health and diet, locally produced. So it is hard to keep up in terms of innovative technology."* Group	Average impact: medium High impact – 32% (6) Medium impact – 32% (6) Limited impact – 21% (4) No impact – 16% (3) I don't know – 0% (0)	Impact level: high Rationale: "The sector is in general, very risk averse as maintaining production stable and product quality/branding are key to profitability. Therefore, any risk, no matter how minimal, should be avoided. Deploying new technologies is	The UK food and drink manufacturers are highly risk averse and are not likely to implement technologies that might lead to production disruptions due to malfunctioning retrofits; compromising product quality or increase in production cost. Therefore, technologies, which have been tried and proven, ideally in the food and drink sector, are more likely to gain traction. As a result the sector enjoys a slow pace of technological change. At the workshop it was suggested that stronger collaboration across the food and drink value chain can strengthen the research base in the UK and help reduce the risk

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			maximise savings" Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the dairy sector' – "*Lack of demonstration in the dairy sector is a key barrier."* Carbon Trust, 2011 Industrial Energy Efficiency Accelerator - Guide to the brewing sector' – "*Scalability of small-scale test results: Brewers may agree that beer made with new technology on a pilot scale tastes just as good, or even better at times but confidence is lacking that this can then be produced on an industrial scale with sufficiently mitigated risks, as there may be no reasonable way to go back"*	Sustainability Manager: *"Wind is considered but the wind is not sufficient to justify the return. Planning is not an issue; the issue is the lack of proven and available energy-efficient technology."*		perceived as very risky and thus new equipment or technologies should be proven else-where and commercialised , ideally, in the same sector. Focus should be on big-ticket items, not on technologies with incremental savings."	of investment in innovative technologies by sharing it among several players. This is a barrier now.

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			Oakdene Hollins, 2011, The Further Benefits of Business Resource Efficiency' – *"In that study many companies cited a lack of suitable projects in resource efficiency with returns that are attractive in comparison to alternative uses of capital as a reason for not undertaking resource efficiency investments"*				
8	Innovation	Lack of reliable and complete information about technical feasibility or savings potential of innovative energy reduction measures. (Imperfect information).	12 sources: Carbon trust, 2011 industrial energy efficiency accelerator - guide to the brewing SECTOR' - "*Lack of awareness of best practice is a key barrier"* CSE, ECI, 2012, what are the factors influencing energy behaviours and decision-making in the non-domestic	2 Interviews: Group Sustainability Manager: *"Wind is considered but the wind is not sufficient to justify the return. Planning is not an issue; the issue is the lack of proven and available energy-efficient technology."*	Average impact: medium High impact – 26% (5) Medium impact – 37% (7) Limited impact – 21% (4) No impact – 11% (2) I don't know – 5% (1)	Impact level: high Rationale: "Proof that technology will work is fundamental and that proof needs to come from an independent source. This is an engineering led issue so the solution should come from	There is a need for greater knowledge sharing and R&D collaboration within the sector to accelerate technology advancement along the curve from demonstration to commercialisation. Shortage of technical knowledge and capacity within the UK food and drink businesses to identify new technologies and measures is a common challenge. Workshop attendees expressed a concern that managers don't know where to start looking for new options and industry wide support can be

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			SECTOR?' – "*Cost-effective energy efficiency measures are often not undertaken as a result of lack of information and indifference toward environmental problems on the part of the managers. Additionally, energy study results or data are not robust enough to support investment decisions*" Russell c. Mckenna, 2009, industrial energy efficiency interdisciplinary perspectives on the thermodynamic, technical and economic constraints' – "*The size of the organisation has a direct influence on its capacity to notice, interpret and respond to energy efficiency opportunities*"	Workshop attendees concluded: "*Proof that technology will work is fundamental and that proof needs to come from an independent source. This is an engineering led issue so the solution should come from engineers. It requires independently verified data and trials in the business. Difficult to produce information that fits all. Evidence should be not only on what works but what doesn't too.*"		engineers. It requires independently verified data and trials in the business. Difficult to produce information that fits all. Evidence should be not only on what works but what doesn't too."	a key to resolve this. Independently verified data on savings potential can further reduce the hesitations of management to consider new technologies. This has been identified as a stronger barrier for SMEs in the sector and is a barrier now.

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			BIS, 2010, manufacturing in the UK: an economic analysis of the SECTOR' – *"Decision makers within the firm are not those people who understand the potential benefits of the project, although they are the ones likely to benefit directly if and when it proves to be a profitable investment. Overcoming this problem relies largely on the energy managers' ability to persuade management that the project is worthwhile"* Best foot forward, 2012, phase I synthesis report: evidence to support the development of a sustainability roadmap for soft drinks' – *"Informational failure around new*				

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			manufacturing ideas and processes" University of Sussex, 5.0 barriers to energy efficiency in brewing' – *"Lack of knowledge or ability to improve skills to identify and/or implement reduction opportunities 'on the shop/production floor'"* Dr Greg Lavery, 2014, food and beverage SECTOR non-labour resource efficiency: unlocking cost savings, jobs and environmental improvements' – *"Lack of Knowledge of the size of the opportunity/case studies with costs, benefits & risks of the solutions"* McKinsey & Co, 2009, pathways to low-carbon economy, version 2 of the global				

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			greenhouse gas abatement cost curve' – *"Lack of awareness - in many case, consumers and businesses are unaware of energy efficiency alternatives and the potential savings they offer. This is sometimes because individual opportunities are small, even while they yield large energy savings in aggregate."* B. Sturm, opportunities and barriers for efficient energy use in a medium-sized brewery' – *"Data is key and not always reaidly available"* Hans Even Helgerud, 2009, energy efficiency in the food and drink industry – the road to benchmarks of excellence' –				

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			"Uncertainty regarding profitability/economic savings"				
9	Operations	Planning constraints and remote location and distance from heat-users prevents adoption of technologies such as renewables and CHP.	n/a	*1 Interview:* Head of Energy Procurement: *"Waste Heat is abundant, so we built a greenhouse. Waste heat energy technology is not viable for us at the moment due to logistics."*	Average impact: limited High impact – 5% (1) Medium impact – 21% (4) Limited impact – 26% (5) No impact – 42% (8) I don't know – 5% (1)	Impact level: medium Rationale: "Planning is of high importance for carbon reduction as it is a particular concern for investment in renewables."	Implementing fairly new technologies such as waste heat energy supply, renewable and CHP technologies is difficult because of infrastructure. If companies were clustered this might make it easier to plan and fund.
10	Operations	Heterogeneity of the area of application of the technology and compatibility issues.	3 sources: Carbon Trust, 2008, Industrial Energy Efficiency Accelerator: Guide to the industrial bakery sector' – *"The retrofitting of technology to older plants may not be feasible. Maintainability – if an installation requires a lot of time-consuming maintenance, there is*	*1 Interview:* Head of Energy Procurement: *"Technologies are out there – so trying to get consensus of which work and which don't is a big challenge"*	Average impact: limited High impact – 5% (1) Medium impact – 11% (2) Limited impact – 32% (6) No impact –21% (4) I don't know – 32% (6)	Impact level: 2 Rationale: "It is difficult to standardise technologies because the sector is so diverse, but still a lot of common technologies are used in different processes."	Compatibility issues are a challenge for implementing new technology as industries do not want to be the first to try out technology as that is risky. Also the areas in which new technology is applied are often very different so to generalise results is a risk.

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			a danger it may fall into disrepair" Carbon Trust, 2011, Industrial Energy Efficiency Accelerator - Guide to the maltings sector' – *"Retrofit may not be technically viable for all sites"* University of Sussex, 5.0 Barriers to energy efficiency in Brewing' – *"Heterogeneity: To clearly identify the importance of this, it would be necessary to conduct survey research focused on a particular technology. However, the results suggest that heterogeneity is an important obstacle for a number of the selected technologies. This is in contrast to the higher education sector where heterogeneity was considered of limited*				

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			importance. A possible reason for the difference is that efficiency opportunities in brewing are frequently process specific and hence less uniform than the generic technologies used in buildings"				
11	Management	Operational planning constraints and need to seek agreement from internationally based head offices.	2 sources: Carbon Trust, 2011 Industrial Energy Efficiency Accelerator - Guide to the brewing sector' – "*The need to seek agreement from internationally based head offices for changes of UK based plants creates a significant barrier to change"* The UK Government's Business Taskforce on Sustainable Consumption and Production, 2008, Decentralised Energy: business opportunity	1 Interview: Sustainability Manager: *"Capex is signed off in Switzerland (above 1 million)"*	Average impact: limited High impact – 5% (1) Medium impact – 21% (4) Limited impact – 26% (5) No impact – 42% (8) I don't know – 5% (1)	Impact level: limited Rationale: "Most of the time, issues only go to the head office (that is internationally based) for very big issues, most issues and decisions are made by local, country-based offices. The issue of internationally based head offices is only a concern for	Many UK head offices are overseas, this delays the decision-making process as sign off for high value funds often needs HQ sign off. This is also a barrier as overseas head offices might not be aware of the need to decarbonise in the UK as Climate Change polices are different internationally.

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			in resource efficiency and carbon management' – "*Planning constraints – fear of delays associated with resolving permissions and discharging conditions are a particular concern for this sector*"			certain companies as it is very dependent on company size and the importance of the issue. "	
12	Innovation	Fragmentation of the UK science base: many universities are reducing their facilities and resources necessary for R&D activities.	1 sources: Russell C. McKenna, 2009, Industrial energy efficiency Interdisciplinary perspectives on the thermodynamic, technical and economic constraint' – *"Fragmentation of the UK science base: many universities are reducing their facilities and resources necessary for R&D activities. This reduces the pool of 'experts' in the field, and makes carrying out R&D projects more difficult.*	1 Interview: Sustainability Manager: *"-Gov doesn't care about the green agenda and the F&D industry is not given any attention by the Government in regards to funding research."*	Average impact: limited High impact – 11% (2) Medium impact – 32% (6) Limited impact – 21% (4) No impact – 26% (5) I don't know – 11% (2)	Impact level: no Rationale: "Currently, there isn't much input from the UK science base, but rather from specialist consultants and we don't' see that changing in the foreseeable future."	There needs to be more University Level research that is freely available to industry. Government needs to take the lead in funding this research.

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			The lack of test/pilot facilities exacerbates the difficulty of testing and evaluation"				
13	Regulation	Low carbon price and its instability.	2 sources: Heather Haydock (Ricardo-AEA) and Tamaryn Napp (Imperial College), Decarbonisation of heat in industry - A review of the research evidence' – *"However, where low carbon options are not ultimately cost negative the current carbon price and its instability is insufficient to facilitate the uptake of these technologies"* FDF, 2013, DEFRA/DECC Review of balance of Competences: Environment and Climate Change Response from the food and drink Federation' – "*The main issue we have on*	*n/a*	Average impact: limited High impact – 11% (2) Medium impact – 26% (5) Limited impact – 36% No impact – 21% (4) I don't know – 11% (2)	Impact level: no Rationale: "Currently it is not perceived as a challenge".	There needs to be a fixed and consistent price on carbon with carbon trading regulations clearly laid out over a 15 or 20 year timeframe, to create a more stable carbon environment for trading.

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			this matter is the UK's unilateral decision to introduce a minimum price for carbon through the introduction of the Carbon Price Support mechanism. This means UK companies are exposed to a much higher cost of carbon than our European competitors. This additional cost burden, which we estimate will cost our sector over £90 million per annum from 2020, will have a detrimental impact on the ability of UK food and drink manufacturers to compete in Europe" The UK Government's Business Taskforce on Sustainable Consumption and Production, 2008, Decentralised Energy: business opportunity in resource efficiency				

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			and carbon management' - *"Regulations should be phased over sufficiently long timescales to provide certainty for business investment. For example, pricing in the cost of carbon requires that carbon trading regulations be clearly laid out over a 15 or 20-year timeframe rather than the current five-yearly cycle"*				
14	Regulation	Lack of harmonised legislation at EU level which creates an unlevelled playing field.	1 source: FDF, 2013, DEFRA/DECC Review of balance of Competences: Environment and Climate Change Response from the food and drink Federation ' – "*The key issue is therefore the extent to which it is necessary to harmonise legislation at EU level in order to*	1 Interview: *Group Sustainability Manager: "There is no consistency with carbon regulation and other legislation at the EU level"*	Average impact: medium High impact – 47% (9) Medium impact – 21% (4) Limited impact – 5% (1) No impact – 26% (5) I don't know – 0% (0)	Impact level: no Rationale: "Currently it is not perceived as a challenge".	There needs to be consistent legislation and policy across the EU to allow a level playing field for healthy competition.

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			provide a level playing field for companies competing both within the Single Market and more globally"				
15	Regulation	Strict regulation on the specifications of some production processes makes it difficult to explore efficiency opportunities.	n/a	1 Interview: Sustainability Manager: "*Product quality and safety is the most important aspect – you cannot compromise on these; even on a perception level. E.g. trial work on heat recovery in bread ovens, people asked first what impact it will have on the product; So decisions and discussion how to optimise product quality and make process more efficient (Food Standard*	Average impact: medium High impact – 37% (7) Medium impact – 26% (5) Limited impact – 26% (5) No impact – 11% (2) I don't know – 0% (0)	Impact level: no Rationale: "These regulatory requirements cover product safety, cleaning and apply to some types of products only – dairy, spirits, etc. It is not perceived as a barrier to energy efficiency but more as a minimum requirement for energy consumption."	Maintaining product quality and safety often stands in the way of energy efficiency schemes. Due to fears that experimenting with new technologies will have negative impacts on the product.

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
				Agency) - food refrigeration, packaging, pasteurisation, so on. "			
16	Operations	Increased vulnerability of food and drink operations to energy security.	4 sources: Carbon Trust, 2010, Industrial Energy Efficiency Accelerator: Guide to the animal feed milling sector' – "-*Energy security - This has led them to investigate opportunities such as distributed generation, combined heat and power (CHP) and biomass"* Carbon Trust, 2011, Industrial Energy Efficiency Accelerator - Guide to the maltings sector' – "*Energy security will be a key barrier in the near future."* DECC, 2011, The Carbon Plan: Delivering our low	n/a	n/a	Impact level: no Rationale: "Simply, there isn't enough fuel for everyone, especially biomass."	Energy security is a growing issue because as resources are depleted the price of energy will go up and energy shortages will become common.

Number	Category	Barriers	Literature review	Interviews	Survey (distribution of responses: % and number)	Workshops	Analysis and interpretation
			carbon future' – "*We face some big challenges to our energy security*" The UK Government's Business Taskforce on Sustainable Consumption and Production, 2008, Decentralised Energy: business opportunity in resource efficiency and carbon management' – *"Perceived higher risks relating to the technology and the cost or price of energy. Increasing vulnerability of food operations to energy security – high value product losses can impact heavily on profitability"*				

Table 11: Barriers

INDUSTRIAL DECARBONISATION AND ENERGY EFFICIENCY ROADMAP TO 2050 – FOOD AND DRINK

APPENDIX C – FULL TECHNOLOGY OPTIONS REGISTER INCLUDING DESCRIPTIONS

APPENDIX C FULL TECHNOLOGY OPTIONS REGISTER INCLUDING DESCRIPTIONS

1. Options Register

Technology options identified in the tables below come from sources listed in the references in section 6 of the main food and drink sector report.

General Energy Efficiency							
Option	**Technology Readiness Level**[5]	**Adoption rate**	**Practical Applicability**	**Capex**[6]	**Capex Data Source**	**CO_2 (C) or Electricity (E) Reduction**	**Reduction Data Source**
Energy management and good maintenance practice	9	30%	80%	£0-200,000	Directly from literature and review from sector team (Carbon Trust, 2010; Carbon Trust, 2012; Muntons, 2013; EC, 2006)	5% (C)	Directly from literature and review from sector team (Carbon Trust, 2011)
Motors, pumps and drives, lighting and HVAC	9	20%	100%	£0-200,000	Directly from literature and review from sector team (Carbon Trust, 2011; EC, 2006)	15% (E)	Directly from literature and review from sector team (Carbon Trust, 2011)

[5] Please note that for cases where no source is provided, expert opinion has been used to evaluate the TRL (technology readiness level).

[6] Capex values shown in the table are for a representative site to which that option applies. While cost input data on some options was available on a per site basis, data for others was expressed differently e.g. cost/tonne of production capacity, cost/tonne of emission. Where necessary, these data have been used to derive representative capex estimates per site, as shown in the table. To account for sectors with diverse site sizes, a range of capex values for standard site categories (e.g. small and large sites) have been developed and then multiplied by the relevant proportion of sites in the sector of that category.

Compressed air	7-9	20%	100%	£0-200,000	Directly from literature and review from sector team (Carbon Trust, 2012)	35% (E)	Directly from literature and review from sector team (Carbon Trust, 2011)
Steam production, distribution and end-use	9	20%	100%	£200,000-500,000	Expert judgement by sector team	20% (C)	Directly from literature and review from sector team (IIP, 2015)

Table 12: General energy efficiency full options register

Energy Efficient Technologies							
Option	**Technology Readiness Level**	**Adoption rate**	**Practical Applicability**	**Capex**	**Capex Data Source**	**CO_2 (C) or Electricity (E) Reduction**	**Reduction Data Source**
Waste heat recovery, CHP and avoiding heat loss	6[7]	45%	90%	£500,000-1,000,000	Directly from literature and review from sector team (Carbon Trust, 2011; DECC, 2013)	11% (C)	Directly from literature and review from sector team (Carbon Trust, 2011; DECC, 2013)
Process design	8	10%	100%	£0-7,000,000	Directly from literature and review from sector team (Carbon Trust, 2012)	30% (C)	Directly from literature and review from sector team (Carbon Trust, 2012)
Factories of the future	4-8[8]	0%	25%	£2,000,000-7,000,000	Expert judgement by sector team	10% (C)	Expert judgement by sector team

[7] LOW CVP, 2013
[8] EC, 2015 and Technology Strategy Board, 2015

New refrigeration technologies	3-9[9]	20%	95%	£0-200,000	Directly from literature and review from sector team (DEFRA, 2014)	35% (E)	Directly from literature and review from sector team (DEFRA, 2014)

Table 13: Energy efficiency technologies full options register

IEEA Technologies							
Option	**Technology Readiness Level**	**Adoption rate**	**Practical Applicability**	**Capex**	**Capex Data Source**	**CO_2 (C) or Electricity (E) Reduction**	**Reduction Data Source**
Mechanical and thermal vapour recompression (MVR and TVR)	8-9	25%	75%	£500,000-1,000,000	Directly from literature and review from sector team (Natural Resources Canada, 2011; Best Foot forward, 2012)	19% (C)	Expert judgement by sector team
Homogenisation	4-6	0%	25%	£200,000-500,000	Directly from literature and review from sector team (Carbon Trust, 2010)	10% (C)	Expert judgement by sector team
Increased use of enzymes	4-6	0%	50%	£1,000,000-2,000,000	Expert judgement by sector team	10% (C)	Expert judgement by sector team
Pasteurisation	4-9[10]	0%	50%	£0-7,000,000	Directly from literature and review from sector team (Carbon Trust, 2010; DECC, 2013)	5% (C)	Directly from literature and review from sector team (Carbon Trust, 2011)

[9] US DOE, 2014 and LANL, 2013

[10] NASA, 2013; Koutchma, 2011; Cánovas, 2010; Koutchma and Keener, 2015 and Koutchma, 2013

Cleaning-in-place (CIP)	6-8	20%	100%	£0-200,000	Directly from literature and review from sector team (Carbon Trust, 2010)	5% (C)	Directly from literature and review from sector team (Carbon Trust, 2011)
Microwave drying and heating	4[11]	5%	25%	£2,000,000-7,000,000	Directly from literature and review from sector team (Carbon Trust, 2010)	5% (C)	Directly from literature and review from sector team (Carbon Trust, 2011)
Advanced oven technology	4[12]	15%	25%	£0-200,000	Directly from literature and review from sector team (Carbon Trust, 2010; DECC)	5% (C)	Expert judgement by sector team
Dewatering before drying	7-9	20%	80%	£0-200,000	Expert judgement by sector team	25% (C)	Expert judgement by sector team
New drying technologies	6[13]	10%	70%	£200,000-500,000	Directly from literature and review from sector team (Carbon Trust, 2011; DECC, 2013)	35% (C)	Expert judgement by sector team
Fluidised bed dryers	9[14]	0%	10%	£500,000-1,000,000	Expert judgement by sector team	63% (C)	Expert judgement by sector team

Table 14: IEEA technologies full options register

[11] NASA, 2013
[12] NASA, 2013
[13] NASA, 2013
[14] GEA Niro, 2015

Low-Carbon Energy Sources

Option	Technology Readiness Level	Adoption rate	Practical Applicability	Capex	Capex Data Source	CO_2 (C) or Electricity (E) Reduction	Reduction Data Source
Electrification of heat	6-9[15]	10%	90%	over £7,000,000	Expert judgement by sector team	100% (C)	Expert judgement by sector team
Fuel shift	5-7[16]	2%	20%	£1,000,000-2,000,000	Directly from literature and review from sector team (Carbon Trust, 2010; Carbon Trust, 2011; DECC, 2013)	5% (C)	Expert judgement by sector team
Biomass and bio-energy	6-9[17]	0%	50%	over £7,000,000	Directly from literature and review from sector team, (Anaerobic Digestion, 2015; Carbon Trust, 2010)	90% (C)	Expert judgement by sector team

Table 15: Low-carbon energy sources full options register

[15] Matthews and Portugués, 2012
[16] SI Ocean, 2015 and E4Tech, 2014
[17] NREL, 2010

Supply Chain Options							
Option	Technology Readiness Level	Adoption rate	Practical Applicability	Capex	Capex Data Source	CO_2 (C) or Electricity (E) Reduction	Reduction Data Source
Food waste reduction	7-9	5%	10%	£0-200,000	Directly from literature and review from sector team, (WRAP, 2014)	5% (C)	Expert judgement by sector team
Packaging reduction	5-9[18]	5%	80%	£200,000-500,000	Directly from literature and review from sector team (Henningsson et al., 2001)	10% (C)	Expert judgement by sector team
Supply chain collaboration	6-7	80%	90%	£2,000,000-over £7,000,000	Directly from literature and review from sector team (Carbon Trust, 2011)	1% (C)	Expert judgement by sector team

Table 16: Supply chain full options register

Carbon Capture							
Option	Technology Readiness Level	Adoption rate	Practical Applicability	Capex	Capex Data Source	CO_2 (C) or Electricity (E) Reduction	Reduction Data Source
Carbon capture (CC)	5-7[19]	0%	unknown	£2,000,000-7,000,000	Directly from literature and review from sector team, (Global CCS Institute, 2011)	50% (C)	Expert judgement by sector team

Table 17: Carbon capture full options register

[18] NASA, 2013 and Technology Strategy Board, 2015
[19] US DOE, 2012

2. Options Classification

As mentioned in appendix A, options were classified into six categories containing 25 options in total: general energy efficiency, energy-efficient technologies, IEEA technologies, low-carbon energy sources, supply chain, and carbon capture. Descriptions of these options are provided in the tables below.

General Energy Efficiency

Option	Description
Energy management	Energy management Energy metering, process control, measurement and verification, energy monitoring and targeting Process optimisation and pinch analysis General good manufacturing practices Production scheduling and avoiding idle equipment running
Motors, pumps, etc.	Correct design, sizing, controls, maintenance High efficiency motors (IE3/4/5) VSDs where applicable Voltage optimisation Improved lighting (LED) especially in cold storage rooms
Compressed air	Avoid use of compressed air (prefer direct driven solutions) General good manufacturing practices and maintenance, frequent leak detection and reparation Improved system design (lay-out, materials, location, etc.) Re-use waste heat from compressors Liquiform process (by Amcor and Sidel)
Steam production	State-of-the-art boiler and steam system (hardware and controls) Inspection and maintenance, insulation, water quality, condensate recovery Direct-fired processes (instead of indirect with steam)

Table 18: General energy efficiency options

Energy-Efficient Technologies

Option	Description
Waste heat recovery	Insulation of equipment and piping (Waste) heat recovery CHP and heat pumps
Process design	Robust design of new processing lines Doing investments based on TCO Sequential air ventilation
Factories of the future	3D-printing, early acceptation of new technologies
New refrigeration technologies[20]	Trigeneration Air cycle refrigeration (reversed Brayton cycle or Bell Coleman cycle) (ad)sorption Solar driven ejector refrigeration system, thermo-electric, stirling cycle, thermo-acoustic, magnetic, solar powered, hyfrig, geothermal, vacuum cooling technologies

Table 19: Energy-efficient technology options

[20] Gradual improvements on existing cooling equipment is considered to be part of general good manufacturing practices (energy management option).

IEEA Technologies

Option	Description
MVR, TVR and other technologies	Mechanical vapour recompression Thermal vapour recompression Reduce boil-off, increase high-gravity dilution, wort stripping column Wort steam injection, microwave wort boiling, merling thin-layer wort boiling
Ultrasonic homogenisation	Ultrasonic and partial homogenisation, reducing head pressure through new orifice design
Enzymes	Increased use of enzymes to prepare food in order to reduce energy Enzymes for hydrolysis, to reduce steeping time Microfiltration, vacuum distillation, molecular sieves, membranes Intermitting milling and dynamic steeping, gaseous SO2 in steeping, alkali steeping
Pasteurisation	Improved regeneration efficiency Pasteuriser hibernation, low-temperature pasteurisation Non-thermal pasteurisation, tunnel pasteurisation Flash pasteurisation, UV pasteurisation or sterilisation High pressure processing or pasteurisation Cold sterile filtration with new filler New technologies for scorching / scalding
Cleaning CIP	Cleaning and sterilisation at lower temperatures, CIP with lower water volumes Ultrasonic cleaning, dry ice cleaning Membrane technologies Ice or whirlwind pigging
Microwave drying and heating	Microwave oven, di-electric drying, microwave (starch) drying
Advanced oven technology	Water bath oven, Shower oven, Steam oven, Hot air oven Optimise damper settings, balance oven airflows, directly driven fans Improved oven controls, improved insulation & sealing Reduction of baking tin thermal mass Heat recovery from ovens, heat pump stove Gas-fired proving
Dewatering (before drying or heating)	Use less water in the initial product mixture Increasing product solids before stoving Germ,fibre or starch dewatering
New drying technologies	Retrofitting conventional heat pumps Enhanced heat pumps, combined heat pumps Drying with superheated steam continuous drying, vacuum drying
Fluidised bed dryers	Fluidised bed dryers (with direct use of gas turbine off-gases)

Table 20: IEEA technology options

Low-Carbon Energy Sources

Option	Description
Electrification of heat	Fuel shift from fossil fuels to (low-carbon) electricity
Fuel shift	Renewable energy, fuel shift (e.g. from oil to gas) Renewable energy or wind power
Biomass or bio-energy	Biomass boilers and biomass CHP Burning maltings co-products or wood chips Anaerobic digestion

Table 21: Low-carbon energy sources options

Supply Chain

Option	Description
Food waste reduction	Food waste reduction in processing plants (limited impact) Avoiding food waste or by-product generation during processes Changing form, shape, taste, colour, etc. to reduce losses
Packaging waste reduction	One-way packaging, avoid re-packaging Smart packaging Use of renewable materials in packaging, food-grade recycling of PP and increased recycling Optimal packaging (design, efficiency) and reduction of resources
Supply chain collaboration	Improved supply chain collaboration Avoid unnecessary transport (for intermediate processes)

Table 22: Supply chain options

Carbon Capture

Option	Description
Carbon capture	Carbon capture and storage/utilisation (CCS/U) Carbon dioxide recovery and purification (e.g. in fermentation)

Table 23: Carbon capture options

INDUSTRIAL DECARBONISATION AND ENERGY EFFICIENCY ROADMAP TO 2050 – FOOD AND DRINK

APPENDIX D – ADDITIONAL PATHWAYS ANALYSIS

APPENDIX D ADDITIONAL PATHWAYS ANALYSIS

1. Option Deployment for Pathways under Different Scenarios

Challenging World

OPTION	ADOP.	APP.	DEPLOYMENT 2014	2015	2020	2025	2030	2035	2040	2045	2050
01 ELECTRIFICATION OF HEAT	10%	90%	0%	0%	0%	0%	0%	0%	0%	0%	0%
02 ENERGY MANAGEMENT & GMP	30%	80%	0%	0%	0%	5%	5%	10%	10%	15%	25%
03 WASTE HEAT RECOVERY / CHP / NO HEAT LOSSES	45%	90%	0%	0%	0%	0%	0%	0%	0%	5%	10%
04 FUEL SHIFT	2%	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%
05 CCS / CCU / CCUS	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%
06 FOOD WASTE REDUCTION	5%	10%	0%	0%	0%	0%	5%	5%	10%	15%	25%
07 PACKAGING REDUCTION	5%	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%
08 SUPPLY CHAIN COLLABORATION	80%	90%	0%	0%	0%	0%	0%	0%	0%	10%	10%
09 MOTORS, PUMPS & DRIVES, HVAC & LIGHTING	20%	100%	0%	0%	0%	5%	5%	10%	10%	15%	25%
10 PROCESS DESIGN	10%	100%	0%	0%	5%	5%	5%	5%	5%	15%	15%
11 FACTORIES OF THE FUTURE	0%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%
12 COMPRESSED AIR	20%	100%	0%	0%	0%	5%	5%	10%	10%	15%	25%
13 BIOMASS / BIOENERGY	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%
14 MVR & TVR	25%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%
15 ULTRASONIC HOMOGENISATION	0%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%
16 INCREASED USE OF ENZYMES TO PREPARE FOOD	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%
17 NEW REFRIGERATION TECHNOLOGIES	20%	95%	0%	0%	0%	0%	0%	0%	0%	10%	15%
18 PASTEURISATION	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	5%
19 CLEANING (CIP)	50%	100%	0%	0%	0%	0%	0%	0%	0%	5%	10%
20 STEAM PRODUCTION, DISTRIBUTION & END USE	20%	100%	0%	0%	0%	5%	5%	10%	10%	15%	25%
21 MICROWAVE DRYING AND HEATING	5%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%
22 ADVANCED OVEN TECHNOLOGY	15%	90%	0%	0%	0%	0%	0%	0%	0%	0%	5%
23 DEWATERING BEFORE DRYING	20%	80%	0%	0%	0%	0%	0%	0%	0%	10%	15%
24 NEW DRYING TECHNOLOGIES	10%	70%	0%	0%	0%	0%	0%	0%	0%	0%	0%
25 FLUIDISED BED DRYERS	0%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure 5: BAU pathway, challenging world scenario

OPTION	ADOP.	APP.	DEPLOYMENT 2014	2015	2020	2025	2030	2035	2040	2045	2050
01 ELECTRIFICATION OF HEAT	10%	90%	0%	0%	0%	0%	0%	0%	0%	5%	10%
02 ENERGY MANAGEMENT & GMP	30%	80%	0%	5%	10%	10%	15%	25%	33%	50%	50%
03 WASTE HEAT RECOVERY / CHP / NO HEAT LOSSES	45%	90%	0%	0%	0%	0%	5%	10%	15%	25%	33%
04 FUEL SHIFT	2%	20%	0%	0%	0%	0%	0%	0%	5%	10%	25%
05 CCS / CCU / CCUS	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%	5%
06 FOOD WASTE REDUCTION	5%	10%	0%	5%	5%	10%	15%	25%	33%	33%	50%
07 PACKAGING REDUCTION	5%	80%	0%	0%	0%	0%	0%	0%	10%	15%	25%
08 SUPPLY CHAIN COLLABORATION	80%	90%	0%	0%	0%	0%	10%	10%	15%	25%	33%
09 MOTORS, PUMPS & DRIVES, HVAC & LIGHTING	20%	100%	0%	5%	10%	10%	15%	25%	33%	50%	50%
10 PROCESS DESIGN	10%	100%	0%	0%	5%	5%	15%	15%	20%	38%	55%
11 FACTORIES OF THE FUTURE	0%	25%	0%	0%	0%	0%	0%	0%	5%	15%	25%
12 COMPRESSED AIR	20%	100%	0%	5%	10%	10%	15%	25%	33%	50%	50%
13 BIOMASS / BIOENERGY	0%	50%	0%	0%	5%	10%	15%	25%	33%	33%	33%
14 MVR & TVR	25%	75%	0%	0%	0%	0%	0%	0%	10%	15%	25%
15 ULTRASONIC HOMOGENISATION	0%	25%	0%	0%	0%	0%	0%	0%	10%	25%	33%
16 INCREASED USE OF ENZYMES TO PREPARE FOOD	0%	50%	0%	0%	0%	0%	0%	0%	15%	25%	33%
17 NEW REFRIGERATION TECHNOLOGIES	20%	95%	0%	0%	0%	0%	10%	15%	25%	33%	33%
18 PASTEURISATION	0%	50%	0%	0%	0%	0%	0%	5%	10%	25%	33%
19 CLEANING (CIP)	50%	100%	0%	0%	0%	0%	5%	10%	25%	33%	50%
20 STEAM PRODUCTION, DISTRIBUTION & END USE	20%	100%	0%	5%	10%	10%	15%	25%	33%	33%	50%
21 MICROWAVE DRYING AND HEATING	5%	25%	0%	0%	0%	0%	0%	0%	5%	10%	25%
22 ADVANCED OVEN TECHNOLOGY	15%	90%	0%	0%	0%	0%	0%	5%	10%	25%	33%
23 DEWATERING BEFORE DRYING	20%	80%	0%	0%	0%	0%	10%	15%	25%	33%	33%
24 NEW DRYING TECHNOLOGIES	10%	70%	0%	0%	0%	0%	0%	0%	10%	25%	25%
25 FLUIDISED BED DRYERS	0%	10%	0%	0%	0%	0%	0%	0%	10%	15%	25%

Figure 6: 60-80% CO_2 reduction pathway, challenging world scenario

OPTION	ADOP.	APP.	DEPLOYMENT 2014	2015	2020	2025	2030	2035	2040	2045	2050
01 ELECTRIFICATION OF HEAT	10%	90%	0%	0%	0%	0%	0%	0%	0%	0%	0%
02 ENERGY MANAGEMENT & GMP	30%	80%	0%	10%	10%	15%	25%	33%	50%	50%	75%
03 WASTE HEAT RECOVERY / CHP / NO HEAT LOSSES	45%	90%	0%	0%	0%	5%	10%	15%	25%	33%	50%
04 FUEL SHIFT	2%	20%	0%	0%	0%	0%	0%	5%	10%	15%	25%
05 CCS / CCU / CCUS	0%	20%	0%	0%	0%	0%	0%	0%	0%	5%	10%
06 FOOD WASTE REDUCTION	5%	10%	0%	5%	10%	15%	25%	33%	33%	50%	50%
07 PACKAGING REDUCTION	5%	80%	0%	0%	0%	0%	0%	10%	15%	25%	25%
08 SUPPLY CHAIN COLLABORATION	80%	90%	0%	0%	0%	10%	10%	15%	25%	33%	50%
09 MOTORS, PUMPS & DRIVES, HVAC & LIGHTING	20%	100%	0%	10%	10%	15%	25%	33%	50%	50%	75%
10 PROCESS DESIGN	10%	100%	0%	0%	5%	15%	15%	20%	38%	55%	55%
11 FACTORIES OF THE FUTURE	0%	25%	0%	0%	0%	0%	0%	5%	15%	25%	50%
12 COMPRESSED AIR	20%	100%	0%	10%	10%	15%	25%	33%	50%	50%	75%
13 BIOMASS / BIOENERGY	0%	50%	0%	0%	0%	0%	0%	5%	10%	15%	33%
14 MVR & TVR	25%	75%	0%	0%	0%	0%	0%	10%	15%	25%	25%
15 ULTRASONIC HOMOGENISATION	0%	25%	0%	0%	0%	0%	0%	10%	25%	33%	33%
16 INCREASED USE OF ENZYMES TO PREPARE FOOD	0%	50%	0%	0%	0%	0%	0%	15%	25%	33%	33%
17 NEW REFRIGERATION TECHNOLOGIES	20%	95%	0%	0%	0%	10%	15%	25%	33%	33%	50%
18 PASTEURISATION	0%	50%	0%	0%	0%	0%	5%	10%	25%	33%	33%
19 CLEANING (CIP)	50%	100%	0%	0%	0%	5%	10%	25%	33%	50%	50%
20 STEAM PRODUCTION, DISTRIBUTION & END USE	20%	100%	0%	10%	10%	15%	25%	33%	33%	50%	50%
21 MICROWAVE DRYING AND HEATING	5%	25%	0%	0%	0%	0%	0%	5%	10%	25%	50%
22 ADVANCED OVEN TECHNOLOGY	15%	90%	0%	0%	0%	0%	5%	10%	25%	33%	33%
23 DEWATERING BEFORE DRYING	20%	80%	0%	0%	0%	10%	15%	25%	33%	33%	50%
24 NEW DRYING TECHNOLOGIES	10%	70%	0%	0%	0%	0%	0%	10%	25%	25%	50%
25 FLUIDISED BED DRYERS	0%	10%	0%	0%	0%	0%	0%	10%	15%	25%	33%

Figure 7: Max Tech pathway without electrifying heat, challenging world scenario

OPTION	ADOP.	APP.	DEPLOYMENT 2014	2015	2020	2025	2030	2035	2040	2045	2050
01 ELECTRIFICATION OF HEAT	10%	90%	0%	0%	0%	0%	5%	10%	15%	25%	33%
02 ENERGY MANAGEMENT & GMP	30%	80%	0%	10%	10%	15%	25%	33%	50%	50%	75%
03 WASTE HEAT RECOVERY / CHP / NO HEAT LOSSES	45%	90%	0%	0%	0%	5%	9%	13%	19%	22%	34%
04 FUEL SHIFT	2%	20%	0%	0%	0%	0%	0%	4%	8%	10%	17%
05 CCS / CCU / CCUS	0%	20%	0%	0%	0%	0%	0%	0%	0%	3%	7%
06 FOOD WASTE REDUCTION	5%	10%	0%	5%	10%	14%	23%	28%	25%	34%	34%
07 PACKAGING REDUCTION	5%	80%	0%	0%	0%	0%	0%	9%	11%	17%	17%
08 SUPPLY CHAIN COLLABORATION	80%	90%	0%	0%	0%	10%	10%	15%	25%	33%	50%
09 MOTORS, PUMPS & DRIVES, HVAC & LIGHTING	20%	100%	0%	10%	10%	15%	25%	33%	50%	50%	75%
10 PROCESS DESIGN	10%	100%	0%	10%	20%	30%	30%	38%	55%	55%	80%
11 FACTORIES OF THE FUTURE	0%	25%	0%	0%	0%	0%	0%	5%	15%	25%	50%
12 COMPRESSED AIR	20%	100%	0%	10%	10%	15%	25%	33%	50%	50%	75%
13 BIOMASS / BIOENERGY	0%	50%	0%	0%	0%	0%	0%	5%	10%	15%	33%
14 MVR & TVR	25%	75%	0%	0%	0%	0%	0%	10%	15%	25%	25%
15 ULTRASONIC HOMOGENISATION	0%	25%	0%	0%	0%	0%	0%	10%	25%	33%	33%
16 INCREASED USE OF ENZYMES TO PREPARE FOOD	0%	50%	0%	0%	0%	0%	0%	13%	19%	22%	22%
17 NEW REFRIGERATION TECHNOLOGIES	20%	95%	0%	0%	0%	10%	15%	25%	33%	33%	50%
18 PASTEURISATION	0%	50%	0%	0%	0%	0%	5%	9%	19%	22%	22%
19 CLEANING (CIP)	50%	100%	0%	0%	0%	5%	9%	21%	25%	34%	34%
20 STEAM PRODUCTION, DISTRIBUTION & END USE	20%	100%	0%	10%	10%	14%	23%	28%	25%	34%	34%
21 MICROWAVE DRYING AND HEATING	5%	25%	0%	0%	0%	0%	0%	5%	10%	25%	50%
22 ADVANCED OVEN TECHNOLOGY	15%	90%	0%	0%	0%	0%	5%	9%	19%	22%	22%
23 DEWATERING BEFORE DRYING	20%	80%	0%	0%	0%	10%	14%	21%	25%	22%	34%
24 NEW DRYING TECHNOLOGIES	10%	70%	0%	0%	0%	0%	0%	9%	19%	17%	34%
25 FLUIDISED BED DRYERS	0%	10%	0%	0%	0%	0%	0%	9%	11%	17%	22%

Figure 8: Max Tech pathway with electrifying heat, challenging world scenario

Collaborative Growth

OPTION	ADOP.	APP.	DEPLOYMENT 2014	2015	2020	2025	2030	2035	2040	2045	2050
01 ELECTRIFICATION OF HEAT	10%	90%	0%	0%	0%	0%	0%	0%	5%	5%	5%
02 ENERGY MANAGEMENT & GMP	30%	80%	0%	5%	5%	10%	10%	15%	25%	25%	33%
03 WASTE HEAT RECOVERY / CHP / NO HEAT LOSSES	45%	90%	0%	0%	0%	5%	5%	10%	10%	15%	15%
04 FUEL SHIFT	2%	20%	0%	0%	0%	0%	0%	0%	5%	5%	10%
05 CCS / CCU / CCUS	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%
06 FOOD WASTE REDUCTION	5%	10%	0%	0%	5%	5%	10%	15%	15%	25%	33%
07 PACKAGING REDUCTION	5%	80%	0%	0%	5%	5%	10%	10%	15%	15%	25%
08 SUPPLY CHAIN COLLABORATION	80%	90%	0%	0%	5%	5%	10%	10%	15%	25%	25%
09 MOTORS, PUMPS & DRIVES, HVAC & LIGHTING	20%	100%	0%	5%	10%	10%	15%	15%	25%	25%	33%
10 PROCESS DESIGN	10%	100%	0%	0%	5%	5%	10%	15%	15%	20%	30%
11 FACTORIES OF THE FUTURE	0%	25%	0%	0%	0%	0%	0%	0%	0%	5%	5%
12 COMPRESSED AIR	20%	100%	0%	5%	5%	10%	10%	15%	25%	25%	33%
13 BIOMASS / BIOENERGY	0%	50%	0%	0%	0%	0%	0%	5%	5%	10%	10%
14 MVR & TVR	25%	75%	0%	0%	0%	0%	0%	0%	5%	5%	10%
15 ULTRASONIC HOMOGENISATION	0%	25%	0%	0%	0%	0%	0%	0%	5%	10%	10%
16 INCREASED USE OF ENZYMES TO PREPARE FOOD	0%	50%	0%	0%	0%	0%	0%	0%	5%	10%	15%
17 NEW REFRIGERATION TECHNOLOGIES	20%	95%	0%	0%	0%	5%	10%	15%	25%	25%	33%
18 PASTEURISATION	0%	50%	0%	0%	0%	0%	0%	0%	5%	10%	15%
19 CLEANING (CIP)	50%	100%	0%	0%	0%	0%	0%	5%	10%	10%	15%
20 STEAM PRODUCTION, DISTRIBUTION & END USE	20%	100%	0%	5%	5%	10%	10%	15%	15%	25%	25%
21 MICROWAVE DRYING AND HEATING	5%	25%	0%	0%	0%	0%	0%	0%	5%	10%	15%
22 ADVANCED OVEN TECHNOLOGY	15%	90%	0%	0%	0%	0%	0%	0%	0%	10%	15%
23 DEWATERING BEFORE DRYING	20%	80%	0%	0%	0%	0%	0%	10%	15%	25%	33%
24 NEW DRYING TECHNOLOGIES	10%	70%	0%	0%	0%	0%	0%	0%	5%	10%	15%
25 FLUIDISED BED DRYERS	0%	10%	0%	0%	0%	0%	0%	0%	0%	0%	5%

Figure 9: BAU pathway, collaborative growth scenario

OPTION	ADOP.	APP.	DEPLOYMENT								
			2014	2015	2020	2025	2030	2035	2040	2045	2050
01 ELECTRIFICATION OF HEAT	10%	90%	0%	0%	0%	5%	5%	10%	15%	25%	33%
02 ENERGY MANAGEMENT & GMP	30%	80%	0%	10%	15%	25%	33%	33%	50%	50%	75%
03 WASTE HEAT RECOVERY / CHP / NO HEAT LOSSES	45%	90%	0%	5%	10%	10%	14%	23%	28%	25%	34%
04 FUEL SHIFT	2%	20%	0%	0%	0%	5%	10%	14%	13%	19%	17%
05 CCS / CCU / CCUS	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%	10%
06 FOOD WASTE REDUCTION	5%	10%	0%	10%	15%	25%	33%	33%	33%	50%	50%
07 PACKAGING REDUCTION	5%	80%	0%	10%	10%	15%	25%	25%	25%	33%	33%
08 SUPPLY CHAIN COLLABORATION	80%	90%	0%	10%	10%	15%	25%	33%	33%	50%	50%
09 MOTORS, PUMPS & DRIVES, HVAC & LIGHTING	20%	100%	0%	15%	25%	25%	33%	33%	50%	50%	75%
10 PROCESS DESIGN	10%	100%	0%	5%	15%	20%	30%	38%	38%	55%	55%
11 FACTORIES OF THE FUTURE	0%	25%	0%	0%	0%	0%	5%	10%	15%	25%	33%
12 COMPRESSED AIR	20%	100%	0%	10%	25%	25%	33%	33%	50%	50%	50%
13 BIOMASS / BIOENERGY	0%	50%	0%	0%	5%	10%	15%	25%	33%	33%	33%
14 MVR & TVR	25%	75%	0%	0%	0%	0%	5%	10%	10%	15%	25%
15 ULTRASONIC HOMOGENISATION	0%	25%	0%	0%	0%	5%	10%	14%	21%	19%	17%
16 INCREASED USE OF ENZYMES TO PREPARE FOOD	0%	50%	0%	0%	0%	5%	10%	33%	33%	50%	50%
17 NEW REFRIGERATION TECHNOLOGIES	20%	95%	0%	10%	15%	25%	25%	33%	50%	50%	75%
18 PASTEURISATION	0%	50%	0%	0%	0%	5%	10%	23%	28%	25%	34%
19 CLEANING (CIP)	50%	100%	0%	0%	5%	10%	14%	23%	28%	25%	34%
20 STEAM PRODUCTION, DISTRIBUTION & END USE	20%	100%	0%	10%	15%	14%	24%	30%	28%	38%	34%
21 MICROWAVE DRYING AND HEATING	5%	25%	0%	0%	0%	5%	10%	14%	21%	19%	22%
22 ADVANCED OVEN TECHNOLOGY	15%	90%	0%	0%	0%	0%	5%	9%	13%	11%	17%
23 DEWATERING BEFORE DRYING	20%	80%	0%	0%	10%	24%	24%	30%	28%	38%	34%
24 NEW DRYING TECHNOLOGIES	10%	70%	0%	0%	0%	5%	10%	14%	13%	19%	17%
25 FLUIDISED BED DRYERS	0%	10%	0%	0%	0%	0%	5%	9%	13%	19%	17%

Figure 10: 60%-80% CO_2 reduction pathway, collaborative growth scenario

OPTION	ADOP.	APP.	DEPLOYMENT 2014	2015	2020	2025	2030	2035	2040	2045	2050
01 ELECTRIFICATION OF HEAT	10%	90%	0%	0%	0%	0%	0%	0%	0%	0%	0%
02 ENERGY MANAGEMENT & GMP	30%	80%	0%	15%	25%	33%	33%	50%	50%	75%	100%
03 WASTE HEAT RECOVERY / CHP / NO HEAT LOSSES	45%	90%	0%	10%	10%	15%	25%	33%	33%	50%	75%
04 FUEL SHIFT	2%	20%	0%	0%	5%	10%	15%	15%	25%	33%	50%
05 CCS / CCU / CCUS	0%	20%	0%	0%	0%	0%	0%	0%	0%	10%	25%
06 FOOD WASTE REDUCTION	5%	10%	0%	15%	25%	33%	33%	33%	50%	50%	100%
07 PACKAGING REDUCTION	5%	80%	0%	10%	15%	25%	25%	25%	33%	33%	33%
08 SUPPLY CHAIN COLLABORATION	80%	90%	0%	10%	15%	25%	33%	33%	50%	50%	75%
09 MOTORS, PUMPS & DRIVES, HVAC & LIGHTING	20%	100%	0%	25%	25%	33%	33%	50%	50%	75%	100%
10 PROCESS DESIGN	10%	100%	0%	10%	20%	30%	38%	38%	55%	55%	80%
11 FACTORIES OF THE FUTURE	0%	25%	0%	0%	0%	5%	10%	15%	25%	33%	50%
12 COMPRESSED AIR	20%	100%	0%	25%	25%	33%	33%	50%	50%	50%	75%
13 BIOMASS / BIOENERGY	0%	50%	0%	5%	5%	10%	10%	15%	15%	25%	33%
14 MVR & TVR	25%	75%	0%	0%	0%	5%	10%	10%	15%	25%	50%
15 ULTRASONIC HOMOGENISATION	0%	25%	0%	0%	5%	10%	15%	15%	25%	33%	50%
16 INCREASED USE OF ENZYMES TO PREPARE FOOD	0%	50%	0%	0%	5%	10%	33%	33%	50%	75%	100%
17 NEW REFRIGERATION TECHNOLOGIES	20%	95%	0%	15%	25%	25%	33%	50%	50%	75%	100%
18 PASTEURISATION	0%	50%	0%	0%	5%	10%	25%	33%	33%	50%	75%
19 CLEANING (CIP)	50%	100%	0%	5%	10%	15%	25%	33%	33%	50%	75%
20 STEAM PRODUCTION, DISTRIBUTION & END USE	20%	100%	0%	15%	15%	25%	33%	33%	50%	75%	100%
21 MICROWAVE DRYING AND HEATING	5%	25%	0%	0%	5%	10%	15%	15%	25%	33%	50%
22 ADVANCED OVEN TECHNOLOGY	15%	90%	0%	0%	0%	5%	10%	15%	15%	25%	33%
23 DEWATERING BEFORE DRYING	20%	80%	0%	10%	25%	25%	33%	33%	50%	75%	100%
24 NEW DRYING TECHNOLOGIES	10%	70%	0%	0%	5%	10%	15%	15%	25%	33%	50%
25 FLUIDISED BED DRYERS	0%	10%	0%	0%	5%	10%	15%	15%	25%	33%	50%

Figure 11: Max Tech pathway without electrifying heat, collaborative growth scenario

OPTION	ADOP.	APP.	DEPLOYMENT 2014	2015	2020	2025	2030	2035	2040	2045	2050
01 ELECTRIFICATION OF HEAT	10%	90%	0%	0%	5%	10%	15%	25%	33%	50%	75%
02 ENERGY MANAGEMENT & GMP	30%	80%	0%	15%	25%	33%	33%	50%	50%	75%	100%
03 WASTE HEAT RECOVERY / CHP / NO HEAT LOSSES	45%	90%	0%	10%	10%	14%	21%	25%	22%	25%	19%
04 FUEL SHIFT	2%	20%	0%	0%	5%	9%	13%	11%	17%	17%	13%
05 CCS / CCU / CCUS	0%	20%	0%	0%	0%	0%	0%	0%	0%	10%	25%
06 FOOD WASTE REDUCTION	5%	10%	0%	15%	25%	33%	33%	33%	50%	50%	100%
07 PACKAGING REDUCTION	5%	80%	0%	10%	15%	25%	25%	25%	33%	33%	33%
08 SUPPLY CHAIN COLLABORATION	80%	90%	0%	10%	15%	25%	33%	33%	50%	50%	75%
09 MOTORS, PUMPS & DRIVES, HVAC & LIGHTING	20%	100%	0%	25%	25%	33%	33%	50%	50%	75%	100%
10 PROCESS DESIGN	10%	100%	0%	10%	20%	30%	38%	38%	55%	55%	80%
11 FACTORIES OF THE FUTURE	0%	25%	0%	0%	0%	5%	10%	15%	25%	33%	50%
12 COMPRESSED AIR	20%	100%	0%	25%	25%	33%	33%	50%	50%	50%	75%
13 BIOMASS / BIOENERGY	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%
14 MVR & TVR	25%	75%	0%	0%	0%	5%	10%	10%	15%	25%	50%
15 ULTRASONIC HOMOGENISATION	0%	25%	0%	0%	5%	9%	13%	11%	17%	17%	13%
16 INCREASED USE OF ENZYMES TO PREPARE FOOD	0%	50%	0%	0%	5%	10%	33%	33%	50%	75%	100%
17 NEW REFRIGERATION TECHNOLOGIES	20%	95%	0%	15%	25%	25%	33%	50%	50%	75%	100%
18 PASTEURISATION	0%	50%	0%	0%	5%	9%	21%	25%	22%	25%	19%
19 CLEANING (CIP)	50%	100%	0%	5%	10%	14%	21%	25%	22%	25%	19%
20 STEAM PRODUCTION, DISTRIBUTION & END USE	20%	100%	0%	15%	14%	23%	28%	25%	34%	38%	25%
21 MICROWAVE DRYING AND HEATING	5%	25%	0%	0%	5%	9%	13%	11%	17%	17%	13%
22 ADVANCED OVEN TECHNOLOGY	15%	90%	0%	0%	0%	5%	9%	11%	10%	13%	8%
23 DEWATERING BEFORE DRYING	20%	80%	0%	10%	24%	23%	28%	25%	34%	38%	25%
24 NEW DRYING TECHNOLOGIES	10%	70%	0%	0%	5%	9%	13%	11%	17%	17%	13%
25 FLUIDISED BED DRYERS	0%	10%	0%	0%	5%	9%	13%	11%	17%	17%	13%

Figure 12: Max Tech pathway with electrifying heat, collaborative growth scenario

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