Department for
Business, Energy
& Industrial Strategy

Barriers and Enablers to Recovering Surplus Heat in Industry

A qualitative study of the experiences of heat recovery in the UK energy intensive industries

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Executive summary

The focus of this report is heat recovery, a process by which (wasted) heat generated by an industrial process is captured and reused, either within the same process, on the same site or by another company or residential development. The recovery and re-use of industrial waste heat has multiple benefits such as reducing fuel demand, reducing energy costs and CO2 emissions.

Industry in the UK has a particularly significant role to play in meeting carbon reduction targets set by the Climate Change Act 2008. This report looks at seven of the most energy intensive industries – cement, ceramics, iron and steel, glassmaking, chemicals, paper and pulp, and food and drink – which account for two-thirds of all industrial emissions. A recent study for BEIS identified large technical and economic potential for heat recovery within these industries that is currently not being realised. This study aims to understand the organisational and commercial barriers to heat recovery and to further identify what can enable the take up of heat recovery technologies.

The findings of this report will feed into Phase Two of the Industrial 2050 Roadmaps project, in which Government is working with industry to develop a series of sector action plans that will help enable transition towards a low carbon economy with a competitive industrial sector. Findings on industry attitudes to investing in onsite heat recovery technologies and selling recovered heat off-site will also contribute to development of specific policy interventions to support the recovery and reuse of waste heat, with capital support for both heat recovery and heat networks announced in November 2015.

Research objectives and methodology

The specific research objectives of this study were to develop a qualitative understanding of:

- knowledge and attitudes of industry towards heat recovery and re-use;
- the process that organisations have gone through to invest in and recover heat, including considerations in decision-making;
- the main barriers to industrial heat recovery and re-use; and
- potential enablers that could overcome barriers and/or increase uptake of industrial heat recovery, including policy implications.

To meet these objectives, 40 qualitative in-depth interviews with energy managers and other senior decision-makers were undertaken in 33 companies across all energy intensive industries, apart from Refineries. Of these, 21 companies recovered some heat from their processes, but only eight of these companies had installed any heat recovery technology in the last five years. The remaining 13 companies that had installed heat recovery, had done so more than five years ago, and had only installed these measures as part of energy efficiency measures that are standard practice for their companies or industry. This is an important caveat to keep in mind when considering the actions of those companies that have installed heat recovery. Interviewees included those responsible for energy management and others with a role in the decision making process for implementing heat recovery technology. Interviews took place across March and April 2015, the majority of which were face to face, with the remainder taking place over the telephone for reasons of convenience.

How energy intensive companies approach energy efficiency and heat recovery

An overarching finding from this study is that companies participating in the study do not appear to see heat recovery as significantly different from other energy efficiency measures. Heat recovery is rarely considered exclusively for the purposes of recovering heat, because as a stand-alone measure it is perceived to have little or no commercial value. Instead, heat recovery is seen as one means among many to reduce overall thermal energy needs. As a result, the nuanced information on what companies do and/or do not do around heat recovery was more limited than anticipated at the start of the study. The factors that affect how companies view energy efficiency can tell us a great a deal about how companies approach or view heat recovery in particular. There are then also barriers and practical issues specific to heat recovery (distinct from energy efficiency), which affect whether the organisation chooses to go ahead with implementation.

The most significant motivations to be energy efficient are related to **the energy intensive nature of what the company produces**. Companies producing a commodity with very high energy costs have strong commercial motivations to be energy efficient as it has a direct impact on profitability. Smaller bespoke producers with relatively low energy costs are less motivated to be energy efficient and, in most cases, have a range of other corporate priorities that sometimes take precedence.

For these companies not motivated exclusively by commercial factors, other **corporate drivers and market related factors** included compliance with regulations, wanting to improve corporate reputation amongst customers, a desire to encourage and embed a culture of sustainability amongst staff and the impacts of the wider economic climate.

The extent to which companies in our sample were motivated to be energy efficient appears to determine the structures they put in place to manage and monitor energy. Table A below illustrates the five different ways companies in our study manage energy.

Table A: How different companies manage and approach energy efficiency

	Team Structure	Approach to energy management
Multi-person teams	**Dedicated energy teams** with multiple dedicated staff	Comprehensive, sophisticated monitoring on a continuous basis. Commercially driven.
	Disparate teams of individuals from across departments/ sites	Sophisticated daily monitoring. Commercial drivers compete with corporate drivers.
	Non-dedicated teams with other responsibilities	Ad hoc monitoring across process as whole. Corporate drivers dominate.

Single individual	**Dedicated individuals** devoted to energy management	Some sophisticated, others ad hoc. Commercial drivers compete with corporate drivers.
	Non-dedicated individuals with other responsibilities	Ad hoc monitoring across process as whole. Corporate drivers dominate.

More specifically, our study shows that two clear company types from analysis of how these companies approach energy management and heat recovery. These companies sit at either end of a spectrum:

- At one end, there are 'super energy intensive companies' where energy accounts for over 50% of operating costs for highly commoditised processes. These companies compete predominantly on price and energy efficiency measures can have potentially enormous impacts on profitability. As a result, these companies are strongly motivated to identify efficiency improvements through a dedicated energy team and input-based Key Performance Indicators (such as the amount of fuel used in specific parts of the industrial process). If heat recovery measures are calculated to provide the best return on investment compared to other energy efficiency improvements, it is pursued by these companies and likely to be installed.
- At the opposite end of the spectrum, are small bespoke producers for whom energy costs are much lower (between 10% and 25%) as a proportion of their operating costs. These companies compete on factors other than price, such as marketing, product quality and specification. The price of the product is not their main consideration, so these companies dedicate less time and resource to energy efficiency, have smaller and less dedicated energy teams and focus on production standards rather than process efficiency because they compete on a wider range of factors. As a result, individuals in these companies who are interested in heat recovery often struggle to find the funds and/or lack the capacity to pursue technical knowledge to produce a business case for heat recovery technologies.

A whole range of organisations sit between these two archetypes, in which energy efficiency in general, and heat recovery in particular, compete with a range of other corporate priorities for resource and attention. This report illustrates the variety of heat recovery journeys that have been taken by the sample in this study and where possible identifies some of the common patterns that emerge in their approaches.

Knowledge and awareness of heat recovery

Companies participating in this study were aware that significant heat was lost in their industrial processes, but the extent of their knowledge varied depending on how much time and resource they dedicated to energy efficiency in general:

- Companies with **expert knowledge** were able to quantify the heat rejected in their industrial process, were aware of the exact temperatures of the heat and had good knowledge of the relative merits of heat recovery technologies. This knowledge was acquired through data and information from sophisticated monitoring procedures, a result of the extensive time and resource dedicated to energy management.

- Companies with **some knowledge** of heat recovery were aware of where they lost heat, but could not quantify or measure the temperature of the heat lost. Generally, these companies had less sophisticated energy monitoring equipment and limited technical experience of heat recovery technologies. These companies acquired their knowledge about heat recovery technologies and options from industry networks, trade associations and previous experience of staff.
- Companies with **little or no awareness** of heat recovery knew their processes rejected heat but did know where, how much or at what temperatures. Typically these were smaller companies, with smaller less dedicated energy teams managing energy in an ad hoc way. Of those who did have some awareness of heat recovery, their knowledge was acquired from suppliers who had approached them in the past about heat recovery options.

Heat recovery journeys

Interviews with the 33 companies in our study revealed that the heat recovery journey comprises three broad steps prior to installation. Not all companies explored heat recovery beyond the identification stage, but our findings illustrate some of the factors and considerations that play a part at this stage. Overall, however, this study found that there was a wide variation in heat recovery journeys as companies were motivated by different commercial, corporate or market drivers. Figure B illustrates the three key steps typically undertaken by these companies.

Figure B: Identifying the different stages in the heat recovery journeys

Identification: how companies become aware of heat recovery was affected by the company's approach to energy management. Companies with dedicated energy teams and a sophisticated approach to energy management would identify opportunities internally and systematically. Other companies identified opportunities internally, but in a more opportunistic way, or relied on approaches from suppliers or universities.

Investigation: this involves gathering further information on technical and practical requirements of heat recovery technologies and a detailed cost assessment. For sophisticated teams, this merged with the identification stage as investigations also took place through detailed audits, though some additional exploration might take place for a new technology.

Business case: the development of a case for the investment in heat recovery technologies would then take place through standard company processes. Across all companies participating in this study similar types of information was required though more detailed evidence was typically required for larger, more energy intensive organisations.

Factors affecting the consideration and implementation of heat recovery

This study also identified factors (discussed in terms of 'barriers and enablers' to heat recovery) that influenced companies' experiences of heat recovery. Three categories of factors emerged from our analysis: **commercial factors,** related to availability of finance or the impact on a company's bottom line; **practical and technical** factors related to industrial processes and heat recovery technologies; and **corporate factors** related to how a company is run.

Commercial factors played a crucial role at both the *investigation stage* and the *business case stage* of the heat recovery journeys. These factors included the following considerations:

- The availability of capital expenditure (CAPEX) funds – this acted as a barrier for smaller companies at *each stage of the journey*; this was not a barrier for large multinational companies, who faced other process and technical barriers.
- Pay-back periods on heat recovery investments were a barrier *at the business case stage* if they did not meet company requirements. Companies typically required a return on their investments within one to three years.
- Even where pay-back periods were satisfactory, other investments also acted as a barrier to companies investing in heat recovery. Pay-back periods for heat recovery, even where they met general company requirements, did not always compare well with other investments that may also be considered less risky.

Practical and technical factors usually played a role at the *investigation stage,* because of the implications for the business case. These factors included:

- Technical challenges for companies in identifying an appropriate heat sink and/or finding a use for available low grade heat as well as integrating new technologies with existing systems.
- The physical structure of a site acting as a barrier to heat recovery. In some cases appropriate heat recovery solutions were too large to be installed on small sites. Other sites were too large to transfer rejected heat to a heat sink.
- Companies having specific concerns about the technical performance and reported paybacks of heat recovery technologies.
- The importance of timing of installation in cases where a system shutdown is needed, which may only happen every couple of years.

Underlying **corporate factors** included corporate priorities and aspects of how a company is run:

- The extent to which energy is a corporate priority and the resources companies commit to monitoring energy consumption influence the willingness and ability of companies to make progress at each stage of the heat recovery journey: companies with sophisticated energy teams and audits are fully aware of possible heat recovery opportunities and able to investigate solutions in detail;

companies committing less resource to energy management were not always aware of the full range of energy efficiency solutions, including heat recovery.

- Where companies do explore heat recovery, other corporate priorities can take precedence in companies who produce variety or bespoke products, meaning that limited investment funds are not directed towards energy efficiency.
- Corporate culture can also mean that heat recovery is pursued for reasons others than the impact on a company's bottom line, for example, where senior managers have a strategic objective to embed a culture of sustainability in company processes and amongst staff.

Conclusions – increasing the take up of heat recovery technologies

This study highlighted commercial, practical and corporate barriers reported as preventing increased take up of heat recovery processes by energy intensive industries. Based on these findings, any measures to increase take-up of heat recovery technologies need to address some of the following issues:

- The **high up-front costs** of heat recovery technologies that are beyond 'business as usual' considerations in these industries. Participants suggested that reducing these through technological innovation or financial support would be of benefit to all companies but in particular smaller companies with more limited access to CAPEX.
- The **long pay-back periods** (over 3 years) companies associate with heat recovery. Improving pay-back periods would benefit the highly commoditised producers who are likely to install any energy efficiency innovation with an acceptable pay-back period. Participants mentioned tariff payments or upfront grants as possible solutions.
- The **lack of confidence in heat recovery technologies** and the payback calculations of suppliers reported by companies in this study. Demonstration projects or independent feasibility studies were described as being beneficial to for companies with a less 'proceduralised' approach to energy management.
- The perceived **risk to the quality of product** and efficiency of processes of integrating heat recovery technologies into existing equipment. Minimising or mitigating these risks through demonstration projects or independent feasibility studies was thought likely to benefit all companies.
- The **relatively low importance placed on energy efficiency** and therefore limited resource committed to managing energy in comparison with other corporate priorities. Encouraging companies to commit additional resource to more sophisticated energy monitoring was thought to help energy managers identify and build business cases for appropriate heat recovery technologies.

1 Introduction

1.1 Background to the project

The UK government is committed to meeting carbon reduction targets set by the Climate Change Act 2008. This requires a reduction in the UK's greenhouse gas emissions by at least 80% (from the 1990 baseline) by 2050. Industry in the UK has a significant role to play in meeting these targets. Industrial emissions are 124MTCO2; almost a quarter of UK total emissions. More specifically, industrial energy demand accounts for 73% of heating[1] and 32% generating[2] of the UK's heat-related CO2 emissions, mostly from fossil fuels. The UK manufacturing industry has a good reputation for energy efficiency and there has been a strong downwards trend on industrial CO2 emissions (see BEIS Heat Strategy 2012).[3]

The eight most heat intensive industries are Cement, Ceramics, Iron & Steel, Glass, Chemicals, Refineries, Paper & Pulp, and Food & Drink. These sectors account for two-thirds of the 124 MTCO2 industrial emissions from generating heat during industrial processes.[4] Energy costs can represent up to 40% of total operating costs in these energy intensive sectors (higher in some individual companies). Measures to reduce energy consumption may, therefore, reduce operating costs and improve competitiveness of UK business, as well as reduce CO2 emissions. Reducing operating costs could also improve companies' competitive position and strengthen local industrial clusters.

1.1.1 Heat recovery and economic benefits for industry

Recovery and re-use of industrial waste heat can help reduce fuel demand, reduce energy costs and CO2 emissions, and potentially increase energy security. A previous study commissioned by BEIS[5] identified a technical potential[6] for heat recovery in the UK energy intensive manufacturing sectors of 11TWh/yr, potentially reaching 28TWh/yr if recovered industrial waste heat can be widely supplied into district heating schemes. Of this, 7TWh/yr may also be economically viable. This corresponds to 2.4% of overall UK industrial heat energy use and around 4% of heat energy use within the leading eight heat intensive sectors (164 TWh/yr excl. power).

Figures 1.1 and 1.2 Heat recovery potential in UK energy intensive manufacturing sectors, source: "BEIS, Potential for Recovering and Using Surplus Heat from Industry, 2014"

[1] BEIS (2011) *Digest of UK Energy Consumption*

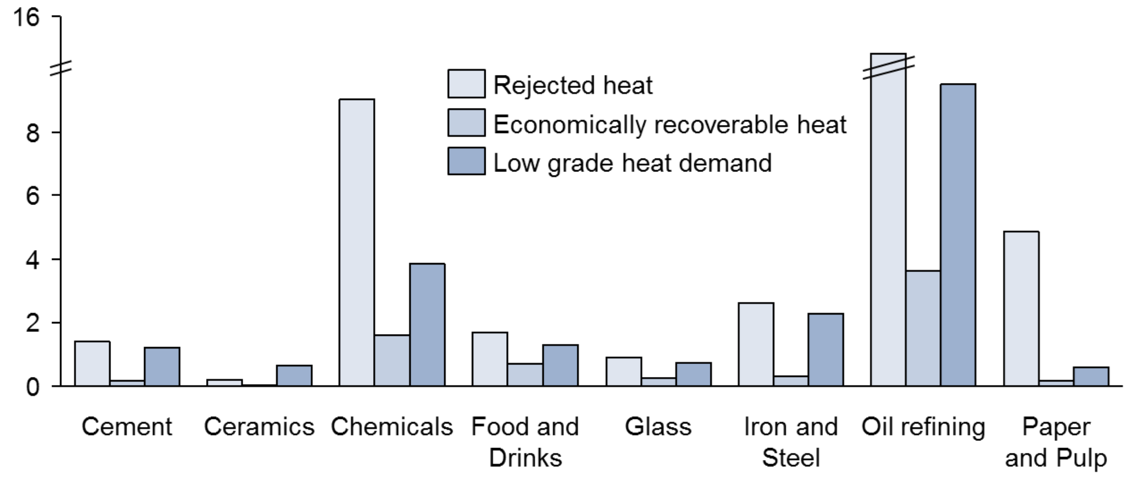
[2] BEIS (2012) *The future of heating: A strategic framework for low carbon heat in the UK*

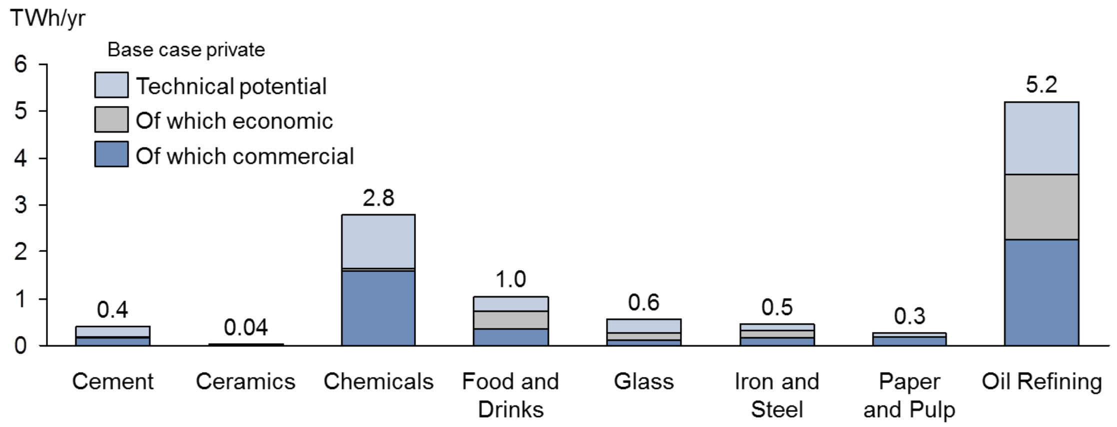
[3] *Ibid*

[4] BEIS (2013) *The future of heating: Meeting the Challenge*

[5] Element Energy et al (2014) *Potential for recovering and using surplus heat from industry*, Report prepared for BEIS

[6] The technical potential is defined based on the projects that together deliver the highest CO2 saving, taking into account "competition" between sources for sinks and technology efficiency.





The technical potential includes contributions from on-site heat re-use, supplying heat 'over-the-fence' to other large industrial users on a nearby site, and conversion to power. All eight heat-intensive industrial sectors could contribute significantly to this potential. For most sectors the demand for low grade heat is a limiting factor for the extent to which rejected heat may be re used on site. All energy intensive manufacturing sectors have heat recovery options which are economically viable.

The previous technical study[7] also calculated that the sectors with the largest potential for industrial heat recovery are oil refining and the chemicals sector. The majority of the economic potential is found in on-site measures where waste heat streams can be further used to pre-heat air and water (beyond business as usual), using recovered heat from flue gases, cooling water reject and low grade steam.

The potential for heat recovery has been recently considered by BEIS as part of the *Industrial Decarbonisation and Energy Efficiency Road Maps to 2050*[8]*.* The reports discuss the potential for, and challenges of, realising carbon dioxide emissions reductions across the eight energy intensive industries in the UK, while remaining competitive. The findings from this study build on this previous work, addressing more specifically questions about the take up of heat recovery technologies.

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[7] *Ibid*

[8] Parsons Brinckerhoff and DNVgl (2015) *Industrial Decarbonisation and Energy Efficiency Road Maps*, prepared for BEIS

The findings of this report will feed into Phase Two of the Industrial 2050 Roadmaps project, in which Government is working with industry to develop a series of sector action plans that will help enable transition towards a low carbon economy with a competitive industrial sector. Findings on industry attitudes to investing in onsite heat recovery technologies and selling recovered heat off-site will also contribute to development of specific policy interventions to support the recovery and reuse of waste heat, with capital support for both heat recovery and heat networks announced in November 2015.

1.2 Aims and objectives

Despite the potential technical and economic benefits of heat recovery and re-use of industrial waste, take up by industry has been slower than anticipated. This study was therefore commissioned by BEIS to better understand the barriers and constraints that may exist in relation to heat recovery, and to further explore the opportunities and decision-making processes that may facilitate further heat recovery in industry. In particular, this research aims to provide BEIS with a more holistic understanding of the issues faced by different sectors and different types of companies. The specific research objectives were to develop a qualitative understanding of:

- knowledge and attitudes of industry towards heat recovery and re-use;
- the process that organisations have gone through to invest in and recover heat, including considerations in decision-making;
- the main barriers to industrial heat recovery and re-use; and
- potential enablers that could overcome barriers and/or increase uptake of industrial heat recovery, including policy implications.

1.3 Overview of the methodology

To address these research questions a qualitative methodology was used to gain a deeper understanding of the constraints and barriers that may exist for different energy intensive companies in relation to heat recovery. Qualitative in-depth interviews were undertaken with energy-intensive companies across seven industrial sectors (Ceramics, Iron & Steel, Glass, Chemicals, Paper & Pulp, and Food & Drink). The oil refining sector was not able to participate in this particular research activity, beyond information already provided as part of the wider 2050 Roadmaps work. Participants from the other sectors included those responsible for energy management and others with a role in the decision making process for implementing heat recovery technology.

The energy intensive industries are diverse, comprising nested levels of industry and type of facility across many different sizes or company. Underneath this is also significant variation in terms of the main or sub-processes that are used within a single site. Typically, it is at the sub-process level that waste heat would be recovered which adds to the variation. Our sample strategy was based therefore on characteristics that relate to how companies produce their products and how they are organised rather than what they produce, i.e. industry classification.

The sample of interest for this study was busy, senior professionals in competitive industries who did not have a great deal of time to spare for a research interview. Some were also reticent to engage in this type of research as they had concerns about confidentiality and anonymity. We therefore adopted a range of recruitment methods (using gatekeepers, existing contacts and generating our own sample lists) to ensure that we were not reliant on a single source or method.

To address some of the challenges of sampling and recruitment across the eight industrial sectors, a **scoping phase** was conducted prior to finalising the research design. This comprised a research design workshop with BEIS, a series of telephone interviews and meetings with 11 Trade Associations and interviews with three technology developers to better understand some of the challenges for industry engaging in the research and to understand their view on heat recovery.

1.3.1 Sampling and recruitment

After consultation with BEIS and several Trade Associations, our sampling strategy aimed to ensure diversity in relation to company characteristics. Rather than simply focusing on sector, we incorporated characteristics that encourage a more nuanced analysis of the experiences and journeys in relation to heat recovery, cutting across industry classifications. Where it was considered useful and possible, we conducted interviews with more than one individual in a single company. Table 1.1 below details our achieved sample of 40 interviews representing 33 companies.

Table 1.1 Company characteristics of final sample

		Recover heat from industrial process		Do not recover heat from industrial process	
		Recently installed additional technology	Recover heat as standard aspect of process	Only considered installing	Not considered installing
		Total 8	**Total 13**	**Total 9**	**Total 3**
Ownership	Multi-national	6	8	6	0
	UK only	2	5	3	3
Size	Small/medium production	1	10	2	3
	Large scale production	7	3	7	0
Temporal profile	Continuous	8	10	9	2
	Batch	0	3	0	1
	TOTALS	**21**		**9**	**3**

A description of the rationale for the inclusion of these sample criteria is included in the methodological appendix at the end of this report. The table shows that out of the 33 companies, 21 recovered heat from their processes, but only eight of these companies had recently (in the last five years) installed any heat recovery technology that was considered beyond what is standard within their industry; nine had considered it seriously (up to different stages) but not taken it further and three had not taken it into consideration at all. Measures were also taken to ensure that all energy intensive industries were represented in the sample, although Table 1.2 shows that we had different levels of success with engagement.

Table 1.2: Distribution of interviews across the energy-intensive sectors

Glass	Food & drink	Iron & steel	Cement	Chemicals	Ceramics	Paper & pulp	Oil refining
5	5	3	4	9	4	3	0

1.3.2 Data Collection

Interviews took place across March and April 2015 and were fully transcribed. The vast majority of these took place face to face and the remainder by telephone as they were considered more convenient for the participant. The format of the interviews were semi-structured questions allowing for particular research areas to be covered and taking into account the limited availability of time for the participants. The themes covered in the interviews were:

- Organisational background and approaches to energy efficiency
- Understanding and awareness of heat recovery and technologies
- Companies' heat recovery 'journey' – how they identified, implemented and installed heat recovery and who was involved
- Factors that acted as barriers and enablers along that journey
- Experiences of using heat recovery technologies
- Views on encouraging further uptake of heat recovery technologies

1.3.3 Data analysis

Data from interview transcripts was organised and analysed using the Framework method, a widely used approach for social policy research. The approach generates summarised matrices of data, ensuring a systematic, comprehensive and transparent approach to analysis. These outputs are then used as the raw material for detailed thematic and case-based analysis. Our analysis of this data focused on identifying emerging themes and points of difference between participants in relation to the key research questions. This approach has enabled us to address the research objectives in detail; identify nuanced differences between participants, or types of participant; and, provide explanations for these differences.

Full details, including the rationale of each stage of the methodology, are provided in the methodological appendix at the end of this report.

2 How companies understand and approach heat recovery

One of the overarching findings of this research is that companies participating in the study typically do not appear to see heat recovery as significantly different from other energy efficiency measures in developing a business case, even if some distinct technical and commercial factors specific to heat recovery ultimately affect the decision on whether to implement. As such, participants described understanding and approaching heat recovery in the same way as any other energy efficiency initiative. This chapter, therefore, considers the *organisational characteristics* that this study suggests may influence the extent to which companies are motivated to take up energy efficiency measures in general. These organisational characteristics and the general approach an organisation takes to 'energy management' also appear to be important factors in the take up of heat recovery opportunities for the companies in our sample.

2.1 Why companies perceive heat recovery as part of their 'energy efficiency' measures

Heat recovery encompasses a range of technological applications for different purposes. This effects how companies consider these opportunities and whether they decide to implement heat recovery technologies. Based on this research, and the previous study on the technical and economic potential for heat recovery conducted for BEIS, we distinguish the following three types of heat recovery, illustrated in Table 2.1 below.

Table 2.1 Applications of heat recovery

Application	Nature of process
Re-using heat in the industrial process	The transfer of thermal energy that would otherwise be rejected (source) to elsewhere in the same process where the heat is needed (a 'heat sink'). This reduces the overall thermal energy demand of the site. This is appears to be equated with energy efficiency.
Re-using heat elsewhere on site	Waste heat can be used for space heating or to generate electricity. In this form of heat recovery the overall amount of thermal energy inputted is not reduced, but there is potential to use the generated electricity elsewhere within the process or site – which would reduce a company's overall energy needs. This is seen as similar to energy efficiency.
Exporting heat offsite	Waste heat from industrial processes can be transferred offsite for use in other industrial processes by nearby businesses or within heat networks. Companies may be paid for this heat but their energy needs are not reduced. This is not seen as an energy efficiency measure.

Companies in our sample typically only considered or implemented heat recovery in relation to saving energy on site, and the majority in relation to reducing the need for thermal energy in the industrial processes they operate. Considering heat recovery for district heating schemes was rare and influenced by a different set of factors as it was not seen as energy efficiency measure for the company (see Box 4.5 on page 44).

Our research revealed that while there are a range of factors driving company behaviour in relation to investments, profitability and legal compliance are paramount. This means that investment in heat recovery is assessed like any other investment and processed like any other energy efficiency investment. Unprompted, participants compared their motivations and experiences of considering and installing heat recovery to other measures that reduce energy demands. This typically included reference to more efficient systems, particularly where replacing older equipment, as well as smaller scale activities such as fitting LED lights and improving insulation. Where organisations had systematic approaches to assess and implement energy efficiency measures, as discussed below, heat recovery measures would typically be incorporated into lists of intended energy efficiency improvements for consideration, rather than being standalone or part of wider site improvement plans (see Chapter 3 for more details on this).

As companies typically perceive heat recovery as one of a number of possible energy efficiency measures, the organisational characteristics that influence approaches to energy efficiency are very similar to the underlying factors that influence companies' approaches heat recovery. These shared characteristics are the subject of the next section. This research also shows, however, that there are other factors affecting the take up of heat recovery which relate to nature of the technologies involved. Heat recovery technologies, for example, were perceived as having higher capital expenditure costs, as requiring new or unproven technologies and involving higher risk due to facility redesign and process integration.[9] These factors – which are outlined as barriers to heat recovery in Chapter 4 – can mean that other energy efficiency measures are considered or implemented instead of heat recovery. This presents clear challenges for the development of policy in this area to ensure that encouraging heat recovery does not displace the implementation of other energy efficiency measures that a company would have implemented instead.

2.2 How organisational characteristics influence motivations for energy efficiency and heat recovery

All the companies that took part in this study were from energy intensive industries and energy efficiency is therefore a major strategic consideration for all. There is, however, significant diversity in the way these companies perceive and approach energy efficiency and therefore heat recovery, as reflected by the recent reports undertaken for BEIS covering eight energy intensive industries. The Industrial 2050 Roadmap research commissioned by BEIS[10], identified a range of enablers and barriers to decarbonisation which explained why companies behaved in different ways towards energy efficiency.

[9] Concerns have been raised in prior research, Element Energy et al (2014) *Potential for recovering and using surplus heat from industry*, Report prepared for BEIS

[10] https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050

This section briefly summarises the findings from our study, which reinforce and build on some of the findings from the Industrial 2050 Roadmaps research.

In describing their approach to energy efficiency, participants in our study identified a range of organisational characteristics that determined the importance of energy efficiency to their company. These factors can be categorised under three headings:

- **Process factors** that relate to the energy intensity of what a company produces;
- **Corporate factors** that relate to how the company is organised and run; and
- **Market factors** that relate to external competition and conditions.

2.2.1 Process related factors

The product(s) that companies produce and the energy intensive nature of the processes required to produce them appear to have a significant bearing on motivations to be energy efficient. This section outlines factors described by participants that relate to the homogeneity of the process and energy costs required to operate these processes.

Commodity vs speciality production

In analysing participants' accounts of how they manage energy, it became clear that the energy intensive nature of processes companies operate is a fundamental motivation for their energy efficient behaviour. The more commoditised a company's product, the more energy efficiency has a direct impact on profitability and competitiveness.

> *It's just a way of life…It's an energy intensive company. It's the culture of how we operate because [energy] is at the core of what we do. So every minute of every day is a different opportunity to optimise and again we've got fairly sophisticated models that help manage that minute-to-minute efficiency.*
>
> (Large, multinational company with dedicated energy team)

These companies, therefore, consider closely all possibly energy efficiency measures including heat recovery. The products and associated processes that participants described by participants in our sample exist along a continuum between commodity production and speciality manufacturers, with a range of 'variety manufacturers' in the middle.

- **Commodity manufacturers** produce a standardised basic product and therefore compete almost exclusively on price. Where energy costs are also high, energy efficiency becomes fundamental to their performance and remaining in business.
- **Variety manufacturers** produce a range of products within a single market or related markets, and compete on a combination of price, marketing and advertising. Energy costs are typically high in absolute terms, but companies have other tools to use to improve their margins.
- **Speciality manufacturers** produce an intermediary or final product, sometimes according to customer specifications. While these companies still operate energy intensive processes, competition in their market is driven less by price, and more

by other variables such as product quality and specification, innovation and design. As a result, cost reduction is less critical to competitiveness.

Energy costs

Relative energy costs, driven by what companies produce and how they produce it, are also a significant driver of energy efficiency. Companies in which energy accounts for over 50% of operating costs can be considered *Super energy intensive* users and will be referred to as such throughout this report. These companies have a strong commercial motivation to save energy:

'Well, when it's [energy] such a big proportion of our operating costs you don't need many other drivers [to be energy efficient].'

(Large, multinational company with dedicated energy team)

'I think it's [energy as a proportion of total costs] about 65 per cent actually. So, anything to do with efficiency, any savings can magnify greatly, any costs can be catastrophic…our challenge is always about energy with that sort of intensity.'

(Large, multinational company with dedicated energy team)

Being out of step with the latest and most sophisticated energy efficiency equipment, including heat recovery technologies, would mean that these companies simply could not compete and would go out of business. Companies with energy costs accounting for between 10% and 25% of operating costs also described energy efficiency as important but described how other concerns within the company often took priority:

Energy costs are around 10%...At the moment it probably sits outside the top two [business priorities]. It would be high up, but obviously, customer focus, building our niche, prestige products, is always going to be at the top or in the top two.

(Medium-sized, multinational company with non-dedicated individual managing energy)

Therefore, while it was important to be energy efficient, motivations to be *as energy efficient as possible* were not quite as high as for the *super energy intensive* companies, where it was paramount.

2.2.2 Corporate drivers

In companies that were not *super energy intensive* users producing commoditised products, a second set of motivations to be energy efficient were related to internal pressures and how companies are organised and run. Participants described the influences of compliance corporate reputation and corporate culture.

Compliance drivers

The requirements of a range of regulations were described by participants as driving their approaches to energy efficiency and the adoption of specific technologies or initiatives such as heat recovery. Regulations (such as EU-ETS, ESOS, CRC and CCA) had an influence in two main ways. Firstly, participants described how specific regulations or agreements *drive their approach* to energy efficiency in general by setting the parameters of what they do.

'We have a climate change agreement with government, so that very definitely means that we have to look at our overall consumption and make sure that we're happy that whatever

investments we can make to reduce our consumption are going to at the very least contribute to us meeting our targets as a company with BEIS'

(Large, domestic company with dedicated energy team)

Secondly, participants also described how compliance with regulations had *influenced internal negotiations* around energy efficiency and had helped them to make their case to senior management:

'[CCA and CRC] has an effect in the sense that it actually helps me to turn round and get some projects through. So, it's a good assister…and we have the added advantage that it reduces our company exposure to taxation and to other forms of carbon leverage that the government put out.'

(Large, multinational company with disparate energy team)

Corporate reputation

Improving corporate reputation by demonstrating a commitment to sustainability was also described as a motivation for being energy efficient. Firstly, participants from companies that are closer in the supply chain to consumers described how customers and clients were demanding a thorough approach to sustainability, and increasingly judging companies on their carbon footprint.

'More and more we see the customers we have don't just mark you on cost, although cost is really important, but some now will look at which has got the lowest carbon footprint, which product is environmentally the most sound. So, we are keen to make sure that we have a sustainability system.'

(Large, multinational company with disparate energy team)

Secondly, participants also described how energy efficiency could influence their reputation relative to their competitors:

'We try to make the most of our successes and communicate that to our customers. I guess the big headline that we had would've been 2013 - which was still used last year as well - was the [trade association] produce a sustainability report in which [this company] were 12.5 per cent lower in terms of carbon emissions than the average across the [trade association's] membership. So that was a huge thing for us to be able to say.'

(Large, domestic company with dedicated energy team)

Corporate culture

Finally creating the right kind of corporate culture was reported as a factor influencing motivations to be energy efficient in two main ways. Firstly, participants described their approach as being influenced by company ethics and a desire '*to do the right thing'*. This, they felt, was distinctly separate from simply the reputational or other benefits that would arise from this. Secondly, participants also referred to a desire to create a *sustainability culture* that would become embedded in their organisation. This was described as encompassing all behaviours, not just industrial processes, with the objective of fostering pride in the company, good employee relations and identifying of cost-saving sustainability solutions.

'the Chairman of the organisation is very keen on sustainability - it is part of a wider culture of building a "nice" organisation…somewhere people want to work. This also takes shape in initiatives related to employee welfare'

(Large, domestic company with non-dedicated energy team)

2.2.3 Market related factors

A final set of factors influencing the extent to which companies were motivated to be energy efficient related to the market. This was most evident in participants' discussions of organisational responses to the economic downturn. Firstly, the response of some companies to the recession was to increase focus on energy management to reduce costs and improve future stability (such as reducing the impact of energy cost changes).

If we're able to predict how much we're using over time and reduce, say, volatility within our usage through leaks or whatever else then it helps the business strategy become more robust to shocks generally.

(Large, multinational company with dedicated individual managing energy)

Conversely, in markets that were less commodity based and less focused on production costs, companies that were struggling financially identified organisational shifts in attention and investment to other areas – such as marketing, or overseas investment.

2.3 How companies manage and monitor energy efficiency

The organisational factors motivating companies to be energy efficient, described in the previous section, encourage companies to manage and monitor energy efficiency in different ways. This section describes the different structures and approaches adopted by companies participating in this study for managing and monitoring energy efficiency. Across our sample of 33 companies, the staff responsible for energy management and improving energy efficiency were structured in five ways, set out in Table 2.2 below.

The following sections briefly describe each team structure in relation their approach to energy efficiency and the characteristics of the companies from which they are drawn. These types are important and instructive for later chapters, as they affect the ability and willingness of companies to consider and take up heat recovery technologies. More detail and further supporting evidence for each of the types in this typology is provided in Annex A.

Table 2.2 Team structures and approaches to energy management

	Team Structure	Approach to energy management
Multi-person teams	**Dedicated energy teams:** staff devoted to energy management and efficiency	Comprehensive, sophisticated and proceduralised monitoring on a continuous basis for each part of the process. Commercially driven.
	Disparate teams: individuals	Sophisticated daily monitoring across process

	from across other departments or across sites	as whole, some highly proceduralised. Commercial drivers compete with corporate drivers.
	Non-dedicated teams: teams with other responsibilities	Ad hoc monitoring across process as whole. Corporate drivers dominate.
Single individual	**Dedicated individuals** whose role is devoted to energy management and efficiency	Some sophisticated daily monitoring across process as whole, others ad hoc. Commercial drivers compete with corporate drivers.
	Non-dedicated individuals who also have other responsibilities	Ad hoc monitoring across process as whole. Corporate drivers dominate

2.3.1 Dedicated teams

Dedicated energy teams comprise multiple staff devoted to energy management and efficiency across all sites and processes. These teams have comprehensive, sophisticated and proceduralised monitoring for each part of the process. Their performances is typically assessed by input-driven KPI's – that is the resources they use rather than the products they produce. This approach was seen as essential to meeting stringent, self-imposed energy targets that were often over and above regulatory requirements in order to stay in business.

Companies with dedicated teams are large, multinational organisations with a turnover of over $1bn. They are *super energy intensive* companies with energy accounting for between 50% and 76% of their total operating costs. In this study, these companies are drawn exclusively from the chemicals and cement industries.

2.3.2 Disparate teams

The disparate teams in our sample comprise a group of people brought together from across departments or sites, with roles not always exclusively devoted to energy. These companies' processes are not as highly commoditised as products produced by companies with dedicated teams but are typically mass produced rather than bespoke. Performance is assessed on the basis of a mixture of input- and output-driven KPIs. They engage in sophisticated daily monitoring across their processes, in some cases in some highly proceduralised way.

These companies are often operate multiple sites or employ large numbers of staff, though they have a wider turnover range than companies with dedicated energy teams. Energy is important, accounting for up to 25% of total costs. The corporate functions of these companies are also diverse and some of the companies are well-known consumer brands from across the seven energy intensive industries included in this study.

2.3.3 Non-dedicated teams

These are coherent teams of people, but chiefly dedicated to a different area of the business with energy an additional responsibility. The products these companies produce are not commodities and in some cases highly bespoke. KPIs, where they exist, therefore relate to the specifications of the product. Monitoring of energy usage and efficiency was described as taking place in an ad hoc fashion, rather than systematic or proceduralised.

This group represents a very small number of the companies in our sample; as such there is more limited detail and diversity contained in the description. The companies in this group are medium in size and drawn from the Glass and Cement sectors, however it is likely that such teams exist in other sectors, particularly Food & Drink and Ceramics.

2.3.4 A dedicated individual

In this group, a single member of staff is devoted entirely to energy management across the company. Companies with a dedicated individual managing energy produce less commoditised, but not entirely bespoke, products. Key Performance Indicators (KPIs) are related to production or output and not efficiency or carbon targets. They focus exclusively on monitoring consumption, identifying efficiencies and achieving certain standards but do ot have the resource to be as systematic as dedicated teams.

Dedicated individuals are typically found in smaller companies (in terms of revenue) some of whom are consumer-facing. Energy is very important to these organisations and a high proportion of their costs (up to 20%). The dedicated individual approach is found across the energy intensive sectors involved in this study, apart from Cement and Iron & Steel.

2.3.5 A non-dedicated individual

A non-dedicated individual describes a single person with responsibility for energy management who also has one or more other unrelated responsibilities. These companies produce a narrow range of products, in some cases bespoke and high-end products produced in made-to-order batches. Energy is less of a priority and the approach of these companies to energy management was therefore typically *ad hoc*. This was because it was of secondary importance compared to other priorities or because staff were constrained by a lack of resource or expertise

Typically, these companies are smaller compared to the rest of the sample and all are small relative to their industry, though some are multi-national. Non-dedicated individuals were identified in companies cutting across all the industries included in this study, apart from Cement.

2.4 How do approaches to energy efficiency influence knowledge and awareness of heat recovery?

The previous section described a series of organisational structures companies put in place to manage energy efficiency, driven by the extent to which companies are motivated to be energy efficient. The structures put in place by the energy intensive companies that participated in this study appear to reflect a range of knowledge and awareness in relation to heat recovery. Participants' knowledge and awareness came from three types of source:

- Within the company: projects or processes run by energy teams, staff members' experience, or knowledge gained from sites in other countries
- Within the industry: from Trade Associations or industry networks
- External sources: from heat recovery technology providers or academics that approach companies or energy consultants approached by companies

This section describes knowledge and awareness in relation to heat rejected in industrial processes and the possible uses for this waste heat and associated technologies.

2.4.1 Knowledge of heat rejected in companies' industrial processes

All companies participating in this study were aware that heat is lost somewhere in their industrial processes. There was, however, varying knowledge of exactly where the heat is lost and how much.

Companies with **high awareness** had detailed knowledge of exactly where heat is lost in their processes. The high level of knowledge and awareness is enabled by companies' proceduralised approaches to energy management adopted by dedicated teams set up as a result of the strong motivations to be energy efficient. They were also able to draw on company experience from overseas and others in the industry. In some cases they drew on information from external sources to supplement existing knowledge. These participants could describe a range of points in the processes where heat is lost and were confident that there was no rejected heat they were not aware of. These companies could also provide quantified measures of the heat rejected at most, if not all, of these stages.

> *'We're putting in 15 megawatts of heat and the energy loss into the building is about 300 watts. That 300 watts is a sufficient heat source to provide natural ventilation to the building.'*

(Medium, multinational company with dedicated energy team)

Companies with high awareness also had a good understanding of the quality of the heat they rejected. Participants were able to identify whether heat was low or high grade, often quoting specific temperatures, as well as assessing whether the heat may be contaminated.

> *'We've got some relatively clean water at 50, 60, up to 70 degree C, and then we've got this vast quantity of our main effluent which is about 95 degrees C, but dirty.'*

(Large, multinational company with dedicated energy team)

Other companies had **some awareness** of the points in their processes where they rejected heat, but they could not be certain they were aware of all of them. These companies typically had non-dedicated teams or individuals managing energy. There was also some awareness in small companies with ad hoc energy management approaches where staff had previous experience of heat recovery or a strong engineering background or an external expert had assessed their industrial processes. However, these companies were also not able to measure the amount of heat they rejected due to limitations of equipment.

'On the electric arc furnace itself, there's a possibility there that we can do some pre-heating of scrap, but we're not the most up-to-date on equipment on-site, a lot of it is quite old pieces of equipment so we don't know how much.'

(Large, domestic company with disparate energy team)

These companies also had some understanding of the quality of heat to the extent that they knew what it might be able to be used for. They were aware of whether the heat might be contaminated in a way that could cause imperfections in their product. These companies were not, however, able to provide exact temperatures of the heat rejected.

Finally, some companies in our sample had **little or no knowledge** of heat rejected in their processes. These are typically smaller companies operating less energy intensive processes and with non-dedicated individuals responsible for energy management who only monitor energy in an ad hoc fashion. This lack of knowledge was not a result of a lack of awareness: these companies were aware that their processes probably rejected heat. There were unsure where and how much, but did not have the time, equipment or expertise to try to find out.

'I don't know too much where it could be recovered and how it could be recovered. In the furnaces…they're heated up for a cycle, say 12 hours, and then they cool down again so how we could make extra use of that, I don't know.'

(Medium, domestic company with non-dedicated individual managing energy)

These companies were confident, however, that if they needed to find out more, they would know where to go for that guidance, citing trade associations in particular.

2.4.2 Knowledge of heat recovery and associated technologies

Companies also demonstrated a wider range of knowledge and awareness of potential uses for rejected heat and the technologies that could support this. The previous section illustrated the influence of company approaches to energy efficiency on knowledge and awareness of rejected heat. While this also influenced knowledge of uses for recovered heat and technologies, this was also influenced by a company's heat recovery journey.

Firstly, companies that had **identified and installed heat recovery technologies** had, unsurprisingly, good knowledge of heat uses and technologies. For smaller companies in this group, detailed knowledge was restricted to the technologies that they had installed. Where companies also had sophisticated knowledge of the general energy efficiency of their processes, they also had good knowledge of all the possible heat uses in their site and a range of technologies.

'Fundamentally, we're doing heat exchange between hot streams and cold streams, whether or not they're process streams or water streams. We've looked at alternatives such as trying to generate electricity from hot water using an Organic Rankine Cycle. Up at [plant location], then, yes, we are involved in discussions around possible district heating systems up there… we do put an awful lot of effort into improving the energy integration and things like that.'

(Large, multinational company with dedicated individual managing energy)

These were not only commoditised producers with dedicated energy teams, but also companies where a single individual had experience of heat recovery from a previous role or the company had been approached by a technology developer or university.

Secondly, companies had some knowledge of heat uses and technologies having **investigated the possibility of heat recovery but not installed any equipment**. In other cases participants were aware of technologies through Trade Association materials or discussions with peers in other companies, but had not investigated further due to limited time or scepticism about the claims made about the performance of specific technologies.

> *'I'm a member of a [Trade Association] and there was a fellow there who gave a presentation…they buy our surplus waste heat and turn it into electricity and we get a proportion of the money generated…that is really in its infancy for us.'*
>
> (Medium, domestic company with dedicated individual managing energy)

> *'We have previously had communications with a company regarding waste heat recovery, and they were doing something with a reverse screw compressor where they were going to turn steam back, steam into electricity. But we didn't go any further with them.'*
>
> (Small, domestic company with disparate energy team)

Finally, a group of small organisations with relatively low energy costs and who gave limited attention to energy efficiency **had no knowledge of the possible uses of recovered heat**. As with knowledge of rejected heat, this was not because of a lack of awareness and they felt confident they would know where to go to find out more.

> *'I'm not actually [aware of heat recovery technologies]. It'd be interesting to find out if there's anything available to mitigate costs anywhere then it'd be useful to look at them. At the [Trade Association] are probably people there to give advice but it's not been my sphere…we don't have an energy manager as such…our main focus has been health and safety.'*
>
> (Large, domestic company with non-dedicated individual managing energy)

2.5 Categorising energy intensive companies by their approach to energy efficiency

This chapter has argued that companies view heat recovery as having the same potential benefits as other energy efficiency investments: saving energy and potentially increasing profitability. From this we can infer that the underlying factors influencing companies to be energy efficient also motivate them to consider heat recovery. Our findings reveal that companies with a greater commercial motivation to be energy efficient had more dedicated and sophisticated teams of people managing energy and monitoring the efficiency of industrial processes. As part of this set up these companies had gained better knowledge and awareness of heat recovery. Participants in other companies, with less incentive to be energy efficient, relied on previous experience and approaches from suppliers or universities for gaining detailed knowledge of heat recovery technologies.

While there are some identifiable patterns in relation to how all of these factors influence heat recovery, there is no clear overall typology of heat recovery journeys that emerges from our data. Two extreme types do emerge: at one extreme is the multi-national commodity producer, where energy accounts for over 50% of operating costs and they have in place a dedicated energy team conducting highly sophisticated and frequent monitoring of energy; at the other extreme are small, domestic single-product producers where energy accounts for less than 10% of operating costs and is managed in an ad hoc manner by an individual with numerous other responsibilities. In between these two extremes exist a wide range of very individual experiences and journeys.

As a result, instead of a definitive typology, the table below sets out six case illustrations with important distinguishing factors developed in this chapter. These case illustrations will be used to articulate how the characteristics in this chapter act as and lead to the enablers and barriers to heat recovery, considered in chapters 3 and 4.

Table 2.3 Case illustrations of types of company and approach to energy efficiency

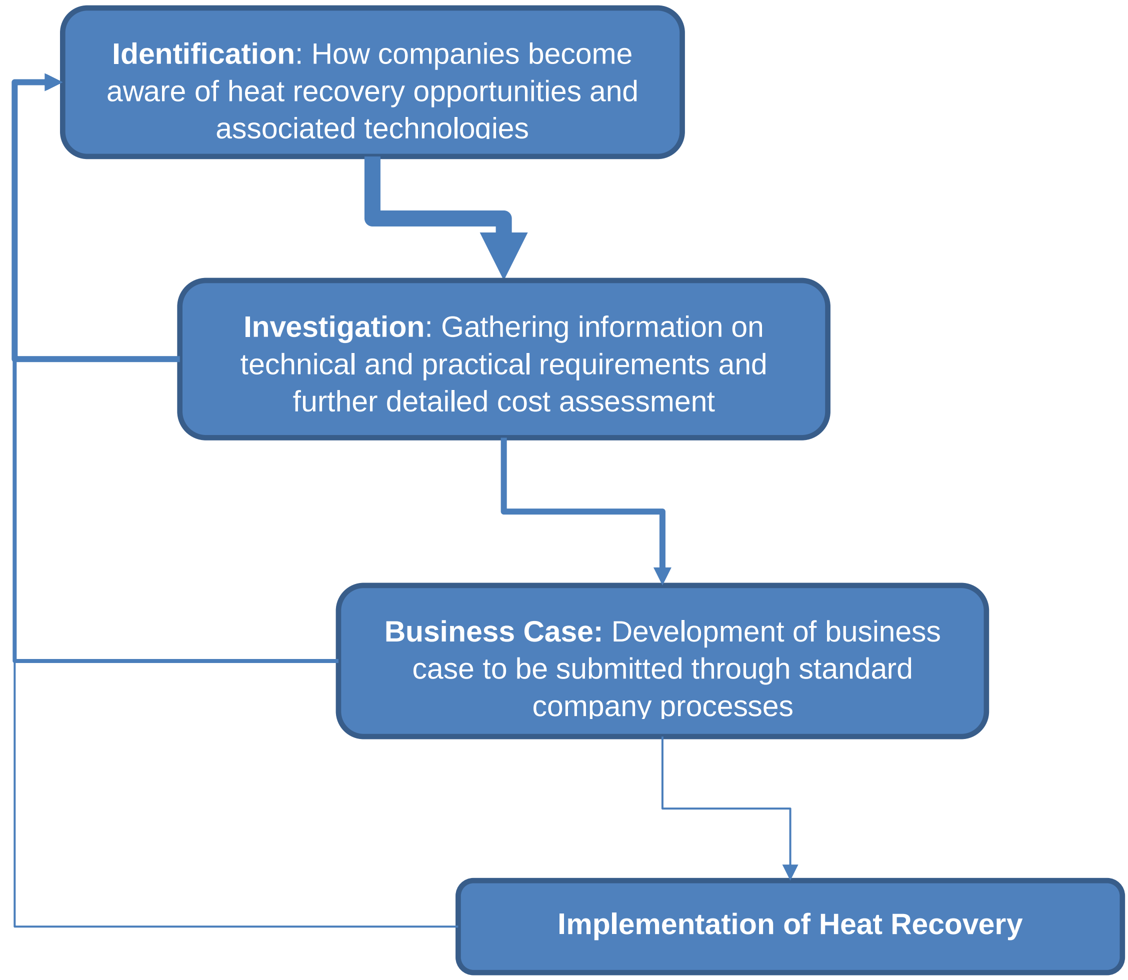
Company	Relative energy costs	Product	Team structure for energy management	Knowledge of heat recovery
Multi-national energy super user	Very high	Commodity	Dedicated team with highly sophisticated and proceduralised approach	Expert
Diversified multi-national brand	Medium	Mass produced	Disparate team with sophisticated approach	Good knowledge
Domestic Low-margin commodity producer	High	Commodity	Dedicated individual with sophisticated monitoring of some parts of process	Some knowledge
Medium size, multi-national prestige producer	Low	Bespoke	Non-dedicated individual, knows where efficiencies are but cannot quantify	Some knowledge
Small domestic, single-product manufacturer	Low	Bespoke	Non-dedicated individual with limited understanding of heat use	Little knowledge
Small domestic, single-site manufacturer	Low	Mass produced	Dedicated individual, monitors what they can but no systematic approach	Some knowledge (through approach from supplier)

3 Heat recovery journeys

3.1 Introduction

Having described the underlying factors influencing energy efficiency motivations and knowledge and awareness of heat recovery more specifically, this chapter describes the key stages that companies (with different structures and decision-making processes) go through prior to implementing heat recovery technology. Figure 3.1 gives a broad overview of the journey. A version of this exists for all companies participating in this study. The point at which the journey ends varies for different companies, as only a small number of organisations had recently implemented a heat recovery measure that was not considered 'business as usual' and commonplace in that industry.

Figure 3.1 Possible steps in the heat recovery journey



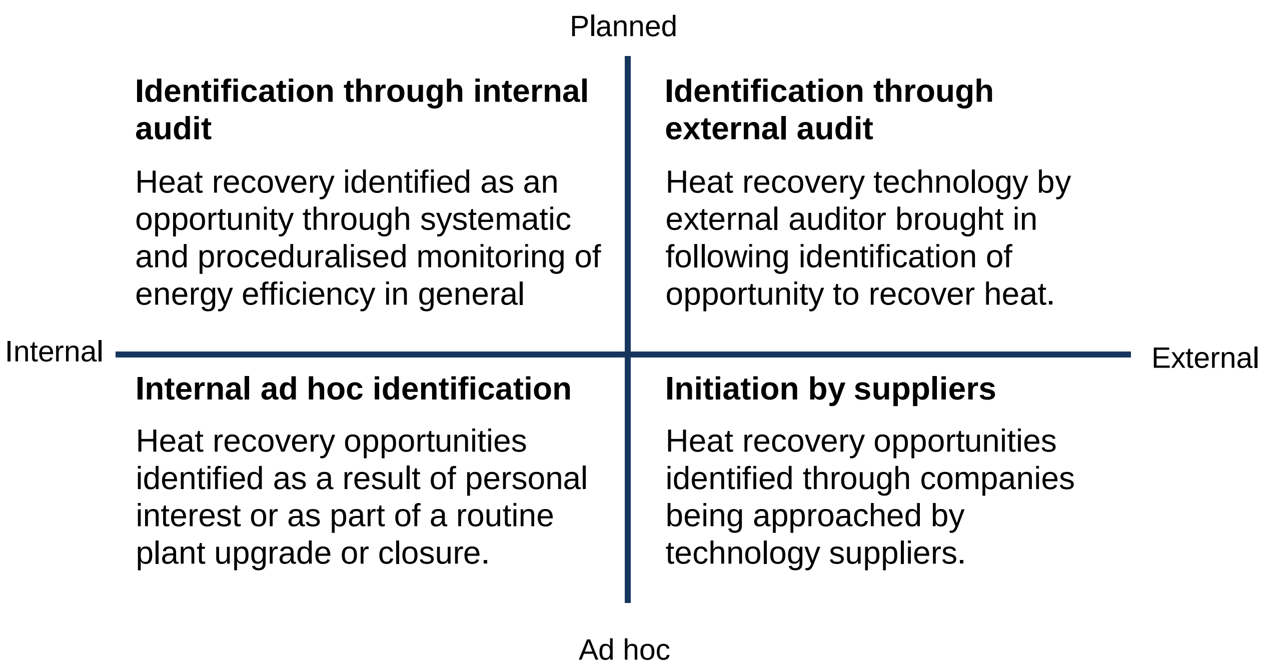
The remainder of this chapter will illustrate the range of journeys that different companies go through in their heat recovery process. The next chapter then discusses the cross-cutting factors that affect progress at each stage of the journey and, ultimately, the take-up of heat recovery technologies.

3.2 Initiation and investigation

This section describes the 'initiation' and 'investigation' stages together, as they are closely related and in some cases simultaneous. The chapter closes by briefly setting out what is involved in developing a business case for different types of organisation. Throughout this section we use the case illustrations set out in Chapter 2 to demonstrate the various ways in which companies experience these stages of the journey and how it leads to the production of a business case.

Participants described the initiation of the heat recovery journey in relation to two dimensions. Firstly, whether a heat recovery opportunity is identified through an audit or in relation to a specific opportunity; and secondly whether this took place internally or externally. In combination these dimensions generate four types of initiation approach, illustrated by Figure 3.2 below.

Figure 3.2: How heat recovery journeys are initiated



3.2.1 Internal audit

The most systematic approach to identification and initiation of heat recovery was through comprehensive auditing of the energy efficiency of industrial processes. This approach was only used by *super energy intensive* companies (companies with energy costs accounting for over 50% of operating costs) who had a dedicated energy team. Heat recovery opportunities were identified along with any other process efficiency opportunity and were assessed in the same way. Box 3.1 below describes how this approach can lead to heat recovery technologies being implemented or not.

Box 3.1: Identification by internal audit, commoditised energy super user

The dedicated energy team at this company completes regular auditing of the energy efficiency of their industrial processes using comprehensive monitoring information. This was described as involving engineers auditing the temperature and composition of waste heat and assessing potential options to improve process and energy efficiency. As a result, a diverse range of potential site improvements are tracked continually and decisions made by the Technical or Production Director on which should be taken forward.

> *"We're always kind of looking ahead, because the plants are on a kind of shutdown cycle where we're looking forward every four years. You're always trying to look ahead to what are we going to do as an improvement project for the next outage, so you're kind of doing your 'optioneering' well up front."*

Heat recovery solutions are assessed against input-based KPIs, evidence that process efficiency and energy efficiency are largely synonymous. Where heat recovery is not attractive relative to other energy efficiency opportunities, this is the end of the journey. Where they do stack-up well against other investments, the team quickly address any possible practical constraints and puts together a business case ready for this year's assessment process. In this sense, the identification and investigation stages are merged in the internal audit approach, except where companies bring in external auditors to validate their work if they are considering a completely new technology.

The team know, however, that even a good business case might not receive approval. They are a multinational company and are in competition for funds with other process improvements and overseas investments. The commercial benefits, however, mean that they a range of heat recovery technologies have been installed in the past:

> *'We've got three bits of kit in place already; a thermocompressor, a condenser, and system of heat exchangers. We're looking at a CHP, but don't think the numbers will add up so we probably won't take that to the board.'*

3.2.2 Internal team identification

'Internal ad hoc identification' of heat recovery opportunities is less systematic. It occurs typically as a result of personal interest or as part of a routine plant upgrade or closure. This approach was identified across all companies in our sample other than those with dedicated energy teams, although it was particularly apparent where individuals within the company had engineering expertise. This internal ad hoc identification was characterised by a more general awareness of where efficiency gains could be made, though these companies had less sophisticated and comprehensive data available on efficiency across the production process. Knowledge of the range of technological solutions that could be applied was also more limited and in some cases would require additional external auditing to make a business case. Box 3.2 below illustrates a heat recovery journey where the opportunity is identified more informally by an individual manager, (i.e. not through a comprehensive audit). A different set of barriers are then present that stop the company actually installing the technology.

Box 3.2: Internal ad hoc identification, Large prestige producer

The dedicated individual responsible for energy management at this company has a long background in engineering. He has identified a range of possible technologies to help the company recover heat and save energy. However, for all technologies that are beyond replacing business as usual heat exchangers, there are a range of barriers to even producing a business case. In some cases the physical attributes of the technologies were not appropriate for installation in the plant; for other technologies he had identified, operational staff were concerned about the impact of reused heat on the quality of their product. The heat recovery journey for this company has not progressed beyond the investigation stage as there was not sufficient support to produce a business case.

However, the case study below demonstrates that journeys beginning with ‘ad hoc identification’ can also be held back by inopportune timing during the business or industrial cycle, as illustrated by Box 3.3 below.

Box 3.3: Internal ad hoc identification, Diversified multi-national brand

The disparate team responsible for energy management at this company has to compete with other areas of the business for investment. The team find that its best opportunity can often be when plant equipment breaks down or is due for a regular replacement. They have been identifying possible heat recovery opportunities and technologies and investigated the practicalities of installing them ready for when this happens.

Prior to the regular replacement of the furnace, the team bring in external auditors as part of a compliance requirement but also ask them to assess the energy efficiency benefits of two heat recovery technologies. One is deemed to be effective and a business case is produced. Feedback from the board, however, is that although the case is strong, investing in energy efficiency is not currently a corporate priority due to market conditions. They recommend that the team come back to them in a year’s time. This is a set-back for the team as the window for making significant changes to the furnace will have passed and the business case for installing this technology will no longer be as strong.

3.2.3 Supplier driven

The third way in which a heat recovery journey was initiated was through suppliers making a direct approach to the company. This was typically the experience of companies producing more bespoke products with dedicated and non-dedicated individuals responsible for energy management. These companies devoted less resource to energy efficiency and did not appear to have the knowledge or time to identify opportunities for heat recovery internally. This process was initiated by the supplier contacting companies and making an initial assessment of the potential for heat recovery, including costs and payback periods. There were two broad outcomes with this approach (illustrated below).

For some companies, following initial investigation the suppler indicated that the project would not be feasible; this was the end of the 'heat recovery journey' for these companies, as highlighted in the Box 3.4 below.

Box 3.4: Supplier driven identification, Small single-product manufacturer

The MD of this company does what he can to manage energy and monitor for efficiencies amongst a whole range of other priorities he has to deal with. '*Energy costs are high*', he says, '*but you've got to pay them*'. Six years ago a technology developer offered to assess waste heat and the cost of installing a heat exchanger. At the time, the MD did not go ahead with it, principally because it was likely to cost too much to pay back within a 'reasonable timeframe' - up to 10 years. Since then he says that he '*hasn't seen or heard of any technological breakthroughs'* that would mean this is more affordable.

In this case, because of the smaller number of people involved and relatively small nature of the business, the stages of the heat recovery journey collapse into one. The person identifying the opportunity is the person involved in approving the 'business case'. If the right pay-back period was available, the MD would install this technology straight away.

Alternatively, where suppliers considered a project feasible, other companies reported that more technical information was gathered by the supplier to provide accurate and detailed costings and forecasts to develop a business case, illustrated in Box 3.5 below.

Box 3.5: Internal ad hoc identification, Large prestige producer

The dedicated individual responsible for energy management at this company was approached by a local university to assess heat recovery opportunities. Having spent time working with the energy manager, the university recommends a specific technology that will pay-back in three years. The energy manager feels this is sufficient to start building a business case. In doing so, he realises that a more detailed investigation of the risks associated with the integration of the technology with existing equipment. The university are unable to provide this information as it is beyond their level of expertise. While it is something the energy manager could attempt, it would take up a lot of his time and he would not feel confident about making the case to the board without a peer review of his work. As he has enough to do monitoring energy of the plant and implementing a separate energy efficiency initiative, he shelves the idea until a quieter time.

As improvements like heat recovery are not part of systematic incremental improvements in site efficiency, they were seen as beyond business as usual for these companies. As a result, this approach was also typically associated with more large scale projects and new technologies, such as Organic Rankine Cycle heat recovery.

3.2.4 External audit

The final approach described by participants was an external audit, although this was rarely used on its own. External audits were commissioned either as supplementary to internal identification of a heat recovery opportunity or in response to external regulations or requirements. Firstly, companies identifying an opportunity internally involved external auditors to investigate the opportunity further where time, skills or knowledge were not available internally, or validate their own work.

Secondly, external audits were also commissioned to meet specific corporate requirements – either for corporate reporting or to meet for customer demands. Amongst less energy intensive companies, participants reported that they would be carrying out external auditing in the future due to the requirements of the Energy Savings Opportunities Scheme (ESOS). Although none had yet carried this out, there was generally positive sentiment about the potential for this auditing to identify new opportunities for energy efficiency across the organisation, including heat recovery.

3.3 Building a business case

All of the companies that took part in this study had maintenance or improvement budgets that were set annually. Projects that could be incorporated within this budget would not need separate Board approval. However, all the heat recovery technologies that had been considered were all beyond the scope of annual budgets, and consequently would require approval. Business cases were considered in two ways:

- **Cyclical consideration:** Companies with more proceduralised approaches to assessing energy efficiency and developed business cases the board as part of a regular and established process in which a large number of improvements are considered at once (following the financial year or production cycles).
- **Ad hoc consideration:** Companies who did not have such proceduralised approaches for considering improvement expenditure developed approaches to the board in a more ad hoc fashion. In this sense they could be considered at any time and cases ranged considerably in how formalised they were required to be.

Despite this difference in the timing of when business cases are considered, there was limited diversity in what was actually involved in developing the business case. All of the participants were involved in, or led, the preparation of a business case for the Board, and the process was identical to that of other energy efficiency or plant improvement measures, which was well understood in all companies. Although, participants described similar business case requirements, our study also found that the information required varied in relation to the financial and technical requirements. Table 3.1 below illustrates the diversity of the information required for business cases although some requirements (e.g. health and safety considerations) were equivalent across the board.

Table 3.1 Information required in business cases

Required information	Differences between companies
Financial • Cost-benefit analysis • Payback period • Capital expenditure (upfront expenditure) • Maintenance expenditure (ongoing costs of implementation)	Larger energy intensive companies require more detailed financial information, such as financial forecasting on energy prices Less detailed information required for the majority of companies. Paramount was certainty around payback periods. Some assessed figures provided by technology suppliers directly within the business cases.
Technical • Technical assessment of heat, including quality and quantity • Impact on processes • Upkeep requirements	Process complexity had an impact on the data required about the practical implications of implementation. Larger companies in particular noted additional regulations that would require additional consideration – including environmental, planning and building

• Environmental impact • Public impact (e.g. local consultation requirements)	regulations.
Wider information • Health & Safety and risk assessments • Strategic 'fit' – assessment of how implementation would fit with other improvements	Required by all.

Having described the variation of heat recovery journeys, the next chapter provides a comprehensive discussion of the cross-cutting factors that affect the stages different companies reach in this journey.

4 Factors affecting the consideration and implementation of heat recovery

4.1 Introduction

The previous chapter described the variety of heat recovery journeys experienced by companies in the energy intensive industries. It illustrated that companies with similar characteristics can have very different experiences. The aim of this chapter is to explore these experiences by describing the wide range of factors that act, at different points in the journey, as barriers or enablers to heat recovery. These factors can be categorised under the following headings:

- **Commercial** factors: relating to the availability of finance or impact of installing heat recovery technology on a company's bottom line;
- **Process-related** factors: relating to the technical and practical specifics of the industrial process or processes a company operates; and
- **Corporate** factors: relating to underlying institutional or cultural characteristics, infrastructure and approach.

Barriers are typically cross-cutting, influencing attitudes and behaviours across the different companies, but in some cases relate only to specific types of organisation or stages of the heat recovery journey. In the cases where heat recovery technologies had been installed, this was often enabled by the absence of some of the generic barriers in that specific case. Other companies have been able to overcome certain barriers by taking mitigating actions, as a result of company characteristics and other specific circumstances.

As noted above, there are few common patterns as to how the factors affect companies; rather they interact in different ways to produce a range of distinct journeys for each company. Table 4.1 below provides a summary of how different factors (or enablers and barriers) affect the heat recovery journeys of companies in our sample in different ways. The darker the shading of red for each cell, the more acute the barrier is for that type of company; where a cell is green, the factor enabled heat recovery to be implemented.

The next three sections describe each set of factors in turn, illustrating the points in the journey that that these are relevant and how they manifest for different types of company. Where specific actions can help overcome or mitigate barriers, these are set out in pull-out boxes.

Red = Barrier (the darker the more difficult to overcome)
Green = Enabler

Table 4.1 Barriers and enablers affecting take up of heat recovery

Area	Cross cutting factors	Multi-national energy super user	Diversified multi-national brand	Medium size, multi-national prestige producer	Small domestic, single-product manufacturer
Process related	Uses of heat	Higher number of heat uses	Lots of uses for heat as diverse processes	Limited use for low grade heat; challenge to integrate into bespoke processes	Heat not frequently recovered
	Assessment of plant or process risks	High impact of risk, but better understanding of risk than other companies	Complex processes, high financial impact of plant closure for multi-nationals	Highly bespoke products production, concern over affecting quality	Highly bespoke facilities, very risk averse
	Confidence in technology	Able to make robust assessment internally but still need extensive trials	Anxiety over being first mover	Anxiety over being first mover	Anxiety over being first mover
	Trust in suppliers	Less likely to use external suppliers to calculate paybacks	Mixed – some trust and some cynicism regarding payback periods	Mixed – some trust and some cynicism regarding impacts on heat quality	Potentially too much trust in suppliers, but scepticism could limit take-up
Commercial	Payback periods	Very short pay-back periods required, most significant barrier	Very short pay-back periods required; heat recovery can meet requirements but then other barriers limit take up	Very short pay-back periods required; heat recovery can meet requirements but then other barriers limit take up	Consider longer payback periods as less commercially focused in some cases, but other barriers limit take up
	Availability of capex	Capex only available if meets stringent pay-back or compliance requirements	Capex more available but many competing investments	Capex limited, only available if meets pay back requirement and low risk	Insufficient capex available
	Competition from other investments	Other energy efficiency investments, process investment and overseas	Other investments across range of other corporate functions	Some competition but capex more of an issue	Some competition but capex more of an issue
	Risk of not achieving paybacks	Payback assessed internally	High risk, given need for short payback periods and opportunity cost.	High risk as lack skills to assess paybacks internally	High risk as lack skills to assess paybacks internally
Corporate	Knowledge and awareness	Not a barrier – knowledge excellent	Only a barrier when making business case	Barrier to investigating options effectively	Barrier to identifying heat rejected and heat uses
	Organisational characteristics and corporate culture	Energy efficiency embedded in corporate culture; main impact of bottom line	Energy competes with range of other priorities	Energy competes with range of other priorities	Cannot assess supplier claims

4.2 Commercial factors

Participants typically described commercial factors as the most important barrier to installing heat recovery. These barriers are significant for all companies that took part in this study apart from some very small companies, where owners may be willing to accept less favourable commercial consequences to install heat recovery due to a personal commitment to sustainability for example. Commercial factors were only enablers where heat recovery could achieve quicker paybacks because companies had high energy costs and a commoditised product. Participants across all other types of companies described very specific commercial conditions that would need to be met for heat recovery to be considered. These barriers typically applied at the point of *building a business case,* unless it was well understood that there would be commercial barriers, where it may stop companies even making it past the *identification stage*.

4.2.1 Availability of funds for investments

The first commercial factor related to the **availability of funds for capital expenditure** (CAPEX). Companies clearly have different levels of CAPEX available based on their profitability and business planning. Participants from large multi-national brands did not describe lack of available CAPEX as a barrier. For large super energy intensive commodity-producing companies CAPEX was not easily available, yet it was much more likely to be available if an investment demonstrated at the *business case stage* that is met other conditions such as required payback periods. For all other organisations, however, participants reported a lack of funds for investment in general as well as for energy efficiency initiatives in particular. Some heat recovery technologies require a significant cost to borne up-front, such as an Organic Rankine Cycle (ORC).

> *'In the UK nobody's been able to come up with anything even remotely attractive from a point of view of the cost side of [ORC]. They're considerably more than we're already paying from grid.'*

(Large, multinational company with disparate energy team)

This puts these technologies out of the scope as early as the *identification stage* for most companies, particularly those with smaller margins. Companies in markets that had been negatively impacted by the recent recession, such as Glass and Paper found accessing funds for investment even more difficult.

Finally, organisations that had limited knowledge and awareness of heat recovery technologies were typically aware only of larger, well-known technologies with high up-front costs, rather than smaller technologies or more incremental improvements. Participants from these companies often, therefore, overstated the CAPEX requirement of heat recovery and describe CAPEX availability as a barrier at the *investigation stage*.

Box 4.1 – Impact of economic conditions on availability of CAPEX

The **large, multi-national prestige producer** cited the recession as substantially limiting the availability of CAPEX for any investment, not just energy efficiency or heat recovery:

In a climate like now where all companies are really highly pressured, and everybody's been feeling essentially the credit crunch. I know we spoke that we're coming out of it, but everybody has streamlined in that time, and there's not a lot of capital going about.

For the **small, domestic single-product company**, increased global competition and falling demand means that any CAPEX that is available is spent on immediate priorities; which, in this case, energy efficiency and heat recovery are not:

The Paper industry in the UK has come under substantial pressure, initially competition from China up from mid-1990s to 2008… then demand for news print has dropped massively, and then the financial crash of 2008, 2009 mean the paper industry is under significant financial pressures. Therefore, there's not as much capital available to invest and what there is has to be used for priority work and heat recovery is a long-term investment return.

4.2.2 Rates of return on investment

Where CAPEX is in principle available for energy efficiency investments, such as heat recovery, a range of other commercial factors then come into play. The **return on investment of heat recovery technologies** was identified as the single most important barrier identified by participants in this study. Companies described different approaches to determining acceptable return rates on their investments, yet these were typically described as between one and three years, with three years being very much described as an upper limit.

> *'Typically, anything less than a two year payback is going to be difficult.'*
>
> (Medium, multinational company with non-dedicated individual managing energy)

Participants in dedicated teams and others with extensive knowledge of heat recovery technologies were able to point to heat recovery installations that had been ruled out at the *identification stage* of the heat recovery journey, because they were well known to have long pay-back periods.

> *'Because they [Heat Exchangers] are very complicated they're very expensive, and for the return you're talking several, several years, multiples; four, five, six, seven year paybacks'*
>
> (Large, domestic company with a dedicated individual managing energy)

This was also a barrier at the *investigation stage* for companies that had conducted external audits through a supplier or a university; it was only at this stage that they became aware of the unacceptable payback period.

Not all companies required payback within three years. Companies open to longer payback period operated a more flexible approach to assessing investment opportunities. These are smaller companies, typically employing fewer than ten people on a single site producing a single product.

Box 4.2 – Senior managers committed to sustainability can overcome the requirement for short pay-back periods

In the **small, domestic single-product company**, the Managing Director was previously in charge of energy management. He played a significant role in pushing through energy efficiency improvements despite longer payback periods, because he felt that it's 'the right thing to do':

> *My colleague… the partial owner of the business and managing director, but always looked into alternative energies, he's always been interested in alternatives. He got approached by a company called [Technology Supplier] who were looking to break into the UK. So he looked at that, and of course there would have been a benefit there, but I think if you looked at it today, [Company] probably wouldn't have fitted the equipment because it doesn't match up to the current business plan of the new SMT for investing money and capital.*

4.2.3 Other competing investments

A third commercial factor affecting the installation of heat recovery technologies was **competition from other potential investments** that a company could make. This was described as coming into play only at the point of *making or considering a business case*. If a heat recovery opportunity meets return on investment rules or is considered to pay back sufficiently quickly as part of the business case, it is then considered on these merits alongside other investment opportunities.

Firstly, participants from companies producing less commoditised products and with a greater number of corporate functions described heat recovery projects as being less attractive in comparison to investments in other parts of the business.

> *"When there's such a large amount of financing involved…if they're going to spend £2 million putting something in they could spend £2 million improving our existing equipment, you know, or distributing that somewhere else within the company'*

(Medium, multinational company with non-dedicated energy team)

Participants from highly commoditised, *super energy intensive* companies described a much smaller range of investment opportunities. Even in these organisations, however, investments in standard maintenance could be more fruitful, particularly where the initial outlay for heat recovery is large.

> *Even with a two year payback the energy efficiency or heat recovery may not get a sniff at the trough if other more projects elsewhere have priority'*

(Medium, multinational company with non-dedicated individual managing energy)

Secondly, participants from *dedicated teams,* and from the more sophisticated and committed *disparate team*s, described that heat recovery projects had been overlooked in favour of other energy efficiency projects. This could include investments that improve the efficiency of the core industrial process (particularly in commoditised companies), or the operations of the company as a whole:

> *We do several capital investment projects each year on energy efficiency, and there might be new vans and drivers or there might be new variables with compressors, but we can always find shorter paybacks than heat recovery at the moment. Much as we'd really like to do the heat recovery, it does seem, a bit like all businesses, there is a limit to the amount of the CAPEX. You have to prioritise on the paybacks.*

(Small, domestic company with disparate energy team)

Finally, in multinational companies, even where a heat recovery project is an attractive investment, the UK may not be the best site to install the equipment.

Box 4.3 – Risk and uncertainty affects assessments of payback period relative to other investments

The specifics of these risks are discussed in the following section as they relate to processes and technologies. However, participants described how implementation risks can specifically affect the expected payback of heat recovery installations. These were of particular concern for the **domestic, low-margin commodity producer** as they lack the expertise or resource to complete initial maintenance required within existing budgets.

> *'…the payback might be three years, four years, or there might be some level of nervousness about it as well. So, generally these type of technologies are problematic, so cost you a lot in maintenance in the early stages. You have to go through quite a lot of pain to get to the point where it works.'*

A range of other companies also cited Risk around expected paybacks would be realised. These companies had identified an opportunity through a supplier approach and did not have the internal expertise to validate the figures provided on performance.

> *'If you're not 100 per cent guaranteed about the paybacks, you're not going to invest''*

(Medium, multinational company with non-dedicated team)

4.3 Process and technology related factors

A second set of factors influencing the take up of heat recovery technologies related to a company's industrial processes and technologies. The evidence here echoes the findings of a previous BEIS report on the technical potential of heat recovery.[11] This section illustrates how these factors affect different companies. These factors typically came into play at the *investigation stage* where having

[11] Element Energy et al (2014) *Potential for recovering and using surplus heat from industry*, Report prepared for BEIS

identified rejected heat in their processes, companies try to identify a heat sink or assess the appropriateness of possible technologies.

4.3.1 Technical issues

Firstly, participants described **technical issues** or limitations within their industrial process that made heat recovery more challenging. These issues, as identified in previous research for BEIS on heat recovery, primarily related to identifying an appropriate heat sink and/or finding a use for available low grade heat. These challenges appeared insurmountable in some case, where companies with dedicated teams described utilising as much rejected heat as they could. In these cases, the heat recovery journey for new technologies that are additional to those already installed would end at the *identification stage*. In companies without dedicated energy teams or sophisticated energy monitoring, a lack of knowledge can also hinder the identification of heat sinks or uses for lower grade heat.

4.3.2 Practical issues relating to the day to day running of the sites

Participants also described a set of **practical barriers related to the set-up and operation of their sites and industrial processes**. The first of these related to the requirement to halt processes while machinery is replaced or updated. This was described as a fundamental challenge for companies operating complex continuous processes. Shutting down processes can be at great cost and present risks around performance following any technical modification.

> *It has to fit in with not just payback time, it has to fit in with product demand because these single stream plants don't shut down.*

(Medium, multinational company with dedicated individual managing energy)

Box 4.4 – Practical barriers to installing heat recovery technologies

In the **medium sized, domestic commodity producer**, the size and age of facilities were described as inflexible, and a barrier to installing heat recovery technology:

> *'Our buildings are over [number] years old, the sites have evolved over time, so space is a problem and we're not looking at one big rectangular building that everything sits inside. There are different buildings with different roof pitches and heights and it makes the installation of things difficult…we don't have space for raw material pre-heating otherwise we would do that, but just because of the size of the sites it just wouldn't fit'*

Companies typically shut down plants to carry out general maintenance on a cycle determined by how long key pieces of equipment last (e.g. seven to ten year cycle for replacing kilns). Participants described that installing heat recovery technologies would need to fit into this cycle. Where companies have dedicated energy teams this happens as a normal part of internal auditing. However, those using external auditors or hearing about heat recovery opportunities through suppliers are not always able to fit this within the maintenance cycle (See box 3.4 in Chapter 3 above). Secondly, practical barriers were also described in relation to the site architecture. On small sites where space is limited, it could be difficult to find the space for additional equipment; on others the opposite was true; highlighting long distances between rejected heat and possible heat sinks.

Box 4.5: Barriers and enablers to 'over the fence' heat recovery

Waste heat from industrial processes can transferred offsite for use in other industrial processes by nearby businesses or within heat networks. In principle, all companies could see the wider value of being involved in such a scheme and were aware that such schemes existed. In our sample, however, experience of over the fence heat recovery was limited. One company was involved in supplying heat to a nearby business on a clustered industrial site. A small number of other companies had been approached by a local authority, housing developer or an energy company to consider the possibility of supplying heat to them. It is not possible, therefore, to be confident that all barriers and enablers to recovering heat for over the fence uses have been identified by this study.

There are however, clear barriers identified in the research to getting involved in district heating schemes for energy intensive companies and a clear set of requirements a provider like a local authority or energy company would have to meet in order for them to do so. The major barriers to over the fence heat recovery are:

- Principally, these companies did not want to become an energy supplier and take on the risks related to securing supply for a housing development or other sources.
- The location of plants as many companies are situated in remote areas and not near any obvious over the fence heat sinks
- Seasonal shut-downs can also work against heat recovery for district heating schemes:

> *'I'm quite happy to deal with the [District Heat Scheme] and offering that local benefit but it is intrusive in our process and when we have our shut down they want the most heat because that always happens in February. So there's a disconnect there as well. Again, suddenly people want to hold us liable for producing volumes of heat, if we're not in production we're not in production and suddenly we're expected to take a penalty for not being in production.*
>
> (Large, multinational company with disparate energy team)

Companies who had been approached about district heat schemes suggested that the expectations of their role in the project were too high – both strategically and financially. Companies want to be involved only in supplying the heat as far as their own 'fence'. Requirements for being involved in such a scheme therefore included:

- A third party to co-ordinate and manage partners and the operation of the network;
- Substantial building or investment in the network infrastructure beyond their own premises should not be the responsibility of the company providing the heat;
- A third party to bear the risk of non-supply to the heat user.

> *"…there's people who can do it, but they need quite a lot of support and funding to get that stuff off the ground, because there's a lot of infrastructure cost. Business doesn't have the money to do that, because it's non-core business."*
>
> *(Large, multinational company with dedicated individual managing energy)*

4.3.3 Specification and performance of heat recovery technologies

The third set of practical and technical barriers relate to the **technical specification and performance** of heat recovery technologies**.** These were typically described as barriers, present at the *investigation stage* as companies assess the efficiency gains different heat recovery technologies can provide. Firstly, participants reported that the bespoke and complex nature of their processes meant that there was no ready-made technology for them to use for the rejected heat they have identified. This was reported by companies that had not installed any heat recovery technologies as well as companies that already used off the shelf products to capture some of their rejected heat but found it difficult to capture heat from other parts of their process.

> *'Internally, on the facilities we have here, we have a lot of smaller heat recovery projects. [But] it requires a lot of investment to produce heat recovery from the furnaces, because you have to attach it, obviously, to your stack, and take account of your emissions abatement.'*
>
> *(Medium sized, multinational company with non-dedicated energy team)*

Where companies operated industrial processes that produce high-end bespoke products, notably in Glass and Ceramics, participants reported concerns about the impact of heat recovery technologies on their products. One view was that heat exchangers were not robust enough to withstand the *'dusty environment and sticky particles'* characteristic of their site. In addition, there was a concern that the performance of the new technology may not be as high as conventional equipment and introduce imperfections into their product, which would not be accepted by their customers. These risks meant that companies were less willing to take heat recovery opportunities to the *business case stage*.

Linked to this, participants in smaller, less energy intensive companies also reported a lack of **confidence in the heat recovery supply chain.** Firstly, where companies were reliant on this external audit for their information about heat recovery, they were not always convinced that the technology providers were any more knowledgeable than their own staff. While providers understood how their technology worked, they were not always able to see all the potential or possible pitfalls of the technology being integrated with a specific industrial process. Participants spontaneously reported a lack of demonstration projects in their sector, particularly in Glass and Ceramics or in relation to ORC technology.

> *'we'd like to see a commercial use of it before we invest…at the moment we see it as risky'*
>
> *(Large, multinational company with disparate team)*

Secondly, and perhaps more importantly, participants also showed concern about the payback calculations made by providers. Participants described direct examples of associated costs being excluded from calculations and, therefore, expected paybacks not being realised.

> *'They [suppliers] use totally unrealistic levels of escalation of energy prices. Often when they're talking to people…they use unrealistic levels of what people are*

actually paying for their electricity. They won't include maintenance costs. They're not always discounting cash flows'

(Large, domestic company with disparate energy team)

Where suppliers are the only source of information on heat recovery, it is difficult to conceive of alternative pathways to heat recovery for these companies if they do not have confidence in the technologies or payback expectations they provide.

4.4 Corporate factors

A third set of factors that affect the take up of heat recovery technologies relate to underlying corporate factors described in Chapter 2. This is based in partly on explicit reporting from participants but is also inferred through the analysis of companies' institutional arrangements alongside their experiences of heat recovery. These factors appear to operate at each of the stages of the heat recovery journey and can be categorised as organisational and related to corporate culture. Each of these is described in turn below.

4.4.1 Company characteristics

As described in Chapter 2, the organisational characteristics influencing the take up of heat recovery reflect the extent to which companies are motivated to be energy effiecient. Firstly, limited or lack of knowledge about energy efficiency in general and heat recovery technologies in particular can be a barrier to heat recovery. This can limit the number and type of heat recovery solutions companies are aware of at the initiation stage, particularly smaller organisations with non-dedicated individuals responsible for energy management. Secondly, these companies typically lacked skills or resources to carry-out detailed audits, and investing in such improvements was not considered a corporate priority.

As a result, these organisations rely on opportunistic approaches from suppliers or universities or external audits, as although this approach was not without any constraints, as discussed in an earlier section of this report. In contrast, companies producing commoditised products with highly sophisticated dedicated teams and some disparate energy teams (both geographically and in terms of the departments from which they are drawn), did not face any barriers in relation knowledge and awareness. They were fully aware of heat recovery opportunities, but practical or commercial barriers prevented the realisation of all of these.

Finally, companies with less sophisticated approaches to energy management appear often to be more attracted to a narrow range of heat recovery solutions. These solutions are those that are most well-known or that are being pushed by suppliers – such as ORC. These projects typically require large amounts of CAPEX and come with associated risks due to the upheaval in installation. These kinds of organisations might be more likely to install heat recovery solutions that have lower CAPEX requirements and fewer risks, such as more incremental process improvements, were they able to identify them through more regular and systematic audits and implement them with internal skills and expertise.

4.4.2 Corporate culture

As discussed in Chapter 2, the corporate culture of an organisation is an important underlying factor that affects how energy efficiency and, therefore, heat recovery are prioritised. Commodity producing companies prioritise energy efficiency as the single most important aspect of gaining a competitive advantage in the market. Alternatively, for large multi-national companies with diverse corporate functions, producing a diverse range of products, energy is one of many priorities. This affects the amount of human resource and technical equipment that is afforded for energy management as, unlike in highly commoditised Chemical industries for example, it competes with a range of other functions – sales, marketing or communications for example.

> *'Since the recession the company has become very streamlined and the time needed to consider projects is not there…employees do more than one role, and things beyond production and the bottom line often get pushed to the bottom of the priority list. Despite the fact that we can all see the benefits we're having [on energy efficiency], it's not directly linked to immediate production.'*
>
> *(Medium sized, multinational company with non-dedicated energy team)*

Finally, all companies described or displayed themselves to some degree as risk averse. This was cited as a general characteristic of these industries but also mentioned specifically in relation to the performance of heat recovery technologies, the potential impact on their process, and the possibility of the technology going out of date very quickly. For a risk averse company, a strongly compelling commercial case would be required to outweigh the combined risks presented by complex heat recovery opportunities.

> *So it's not a simple: payback works, energy works…but then we haven't got a product for our customers, can we build stock enough to have a three month outage to install a new technology? The answer probably is, no. It's a multi-faceted problem.*
>
> *(Medium sized, multinational company with dedicated individual managing energy)*

Box 4.6: Companies who have not considered heat recovery

Although the sample was chosen to concentrate on those who had considered heat recovery, three companies who participated had not considered heat recovery at all, beyond what would be considered 'business as usual', industry standard technologies. Because of this low number of interviews, it is difficult to identify specific barriers or enablers that might encourage them to consider heat recovery. However, it is clear that these cases were the most different from those Super energy intensive users, based on the factors identified in Chapter 2. They were less likely to consider energy efficiency at all, and where doing had limited knowledge and awareness of improvements that could be made. There was some evidence that this group were involved with Trade Associations for their sectors, or sub-sectors, but to a much lesser degree than those who were more advanced in their energy efficiency approaches. Further research, looking at energy efficiency more generally, would be very helpful for identifying what measures could be developed to encourage more behaviour from this group.

5 Conclusions – increasing take up of heat recovery technologies

5.1 What this research has found

This research has explored attitudes and behaviours in relation to industrial heat recovery of 40 energy managers and other senior staff from 33 companies in the energy intensive industries. An important finding from our study is that heat recovery is rarely considered on its own merit or exclusively for recovering heat *per se*. Instead, on site heat recovery is seen by companies as one *means* to reducing overall thermal energy needs and therefore considered as part of companies' wider energy efficiency approaches. However, a number of challenges specific to heat recovery affect decisions on whether to proceed. As a result, this report has set out the underlying factors that motivate companies to be energy efficient in general as well as a series of barriers and enablers that specifically related to heat recovery. We now summarise these findings here.

5.1.1 Underlying factors influencing companies' motivations to be energy efficient

Energy intensive companies are similar to each other in the sense that the energy they use represents a higher proportion of operating costs compared to other companies. Despite this, our research has illustrated significant diversity within the group with respect to how they manage and monitor energy, and identify and carry out energy efficiency improvements. Therefore, the ability and willingness of companies to progress in their heat recovery journey is influenced by a series of underlying factors that relate to a company's relative energy costs and the nature of their processes. At the end of Chapter 2, we identified two company archetypes that sit at either end of a spectrum that emerges from this analysis:

- Super energy intensive companies (energy accounting for over 50% of operating costs), with highly commoditised processes that compete predominantly on the cost of their product. Such is the importance of energy efficiency to profitability that these companies have a dedicated energy team geared towards the identification of efficiency improvements.
- At the opposite end of this spectrum are companies for whom energy costs are relatively much lower, and who compete on attributes other than price. These more specialised manufacturers have smaller, less dedicated energy teams and focus on energy amongst other corporate priorities.

A whole range of organisations sit between these extreme examples. Few patterns emerged from this study to neatly categorise this group as they have very distinct processes and heat recovery journeys. However, this depiction of approaches to energy efficiency in the energy intensive industries is important as it provides the context in which to understand the heat recovery journeys that companies are willing or able to take.

5.1.2 The heat recovery journey

Chapter 3 described how the heat recovery journey itself comprises three broad steps prior to installation, illustrated by Figure 5.1 below:

Figure 5.1 Summary of steps in the heat recovery journey

Identification: how companies become aware of heat recovery was affected by a company's approach to energy management. Companies with dedicated energy teams and a sophisticated approach to energy management would identify opportunities internally and systematically. Other companies identified some opportunities internally, but in a more opportunistic way, or relied on approaches from suppliers or universities.

↓

Investigation: this involved gathering further information on technical and practical requirements of heat recovery technologies and a detailed cost assessment. For sophisticated teams, this merged with the identification stage as investigations also took place through detailed audits, though some additional exploration might take place for a new technology

↓

Business case: the development of a case for the investment in heat recovery technologies would then take place through standard company processes. Across all companies participating in this study similar types of information was required though more detailed was typically required for larger, more energy intensive organisations.

These steps are merged in some cases, and some companies do not travel beyond the identification stage.

Chapter 4 then identified a number of barriers and enablers that can halt or accelerate companies' progress to installing heat recovery technology at each stage of this journey. These barriers and enablers can be categorised under three headings and affect different companies in different ways:

- **Commercial factors:** the availability of CAPEX acted as a barrier for smaller companies at each stage of the journey; this was not a barrier for large multinational companies. Pay-back periods on heat recovery investments were a barrier for all companies at the business case stage where heat recovery technologies did not always compare well with other investments due to high up-front costs.

- **Process and technology related factors:** these factors come into play at the investigation stage. Identifying a heat sink and integrating heat recovery technologies with existing equipment could be a barrier, including the timing required for installing equipment (where some shut down is required). The physical structure of a site can act as a barrier, with sites too small for some technologies. Companies also described some scepticism about the technical performance and reported paybacks of untested technologies.
- **Corporate factors:** these are more underlying factors that affect companies' ability and willingness make progress at each stage of the journey. Companies with sophisticated energy teams and audits are fully aware of possible heat recovery opportunities and able to investigate possible solutions in detail. Companies with less resource to commit to energy management and/or where energy is less of a corporate priority are not always aware of the full range of energy efficiency solutions or have more important corporate priorities in which to invest.

The next section considers what can be done by government and other stakeholders to overcome these barriers and encourage the enabling conditions to increase the take up of heat recovery.

5.2 Implications for increasing the take up of heat recovery technologies

The previous study of heat recovery for BEIS by Element Energy identified significant technical and economic potential for heat recovery which were reported by energy intensive industries.[12] The study highlighted some of the technical and economic factors that were reported to hinder the take up of heat recovery processes. Our study has attempted to build on these findings, as well as highlight other commercial, practical and corporate barriers that are preventing the maximum take up of heat recovery processes by energy intensive industries. Based on these findings, participants identified a number of issues that would need to be addressed to improve the take-up of heat recovery technologies:

- The **high up-front costs** of heat recovery technologies that are beyond 'business as usual' considerations in these industries. Participants suggested that reducing these through technological innovation or financial support would be of benefit to all companies but in particular smaller companies with more limited access to CAPEX.
- The **long pay-back periods** (over 3 years) companies associate with heat recovery. Improving pay-back periods was thought by participants to benefit

[12] Element Energy et al (2014) *Potential for recovering and using surplus heat from industry*, Report prepared for BEIS

the highly commoditised producers who are likely to install any energy efficiency innovation with an acceptable pay-back period. Participants mentioned tariff payments or upfront grants as possible solutions.

- The **lack of confidence in heat recovery technologies** and the payback calculations of suppliers reported by companies in this study. Demonstration projects or independent feasibility studies were described as being beneficial to for companies with a less 'proceduralised' approach to energy management.
- The perceived **risk to the quality of product** and efficiency of processes of integrating heat recovery technologies into existing equipment. Minimising or mitigating these risks through demonstration projects or independent feasibility studies were thought by participants to be useful to all companies.
- The **relatively low importance placed on energy efficiency** and therefore limited resource committed to managing energy in comparison with other corporate priorities. Encouraging companies to commit additional resource to more sophisticated energy monitoring was thought by participants to help energy managers identify and build business cases for appropriate heat recovery technologies.

Methodological appendix

This study aimed to better understand the barriers, constraints, opportunities and decision-making processes in industry with regards to heat recovery. The need to understand the behaviours and experiences of companies in detail called for a qualitative methodology to meet these aims. The research comprised 40 in-depth interviews with those responsible for energy management and those with a role in the decision making process for implementing heat recovery technology in their organisations. This section describes in more detail the scoping activities, sample design, the fieldwork and analysis approach.

Scoping phase

Prior to conducting the main research activities, a scoping stage was carried out to inform the sample design, secure sample access and guide the coverage of the interviews. This comprised:

- A **design workshop** with key stakeholders within BEIS to help fully articulate and finalise the research objectives.
- A series of **telephone calls and meetings with 11 Trade Associations**. These discussions were used to anticipate potential challenges to recruiting within specific industries, as well securing support from the associations for the aims of the project.
- A set of **scoping interviews with three technology developers**. These interviews explored developers' engagement with industry, their view of the barriers and challenges that their customers and potential customers face investing in and installing heat recovery technologies.

Sample design

The sample design for the main stage interviews was agreed with BEIS following the scoping stage and subsequently reviewed after the first five interviews had been conducted. Rather than simply focusing the sampling criteria around industry, the design incorporated a number of characteristics to ensure that the sample incorporated a range of views around heat recovery and encouraged a more nuanced analysis of the experiences and journeys that is able to cut across industry classifications. Where possible and necessary, we conducted interviews with more than one individual in a single company. Table 6.1 below illustrates our achieved sample of organisations, from which the 40 interviews were sourced.

Table 6.1 Achieved sample

Criterion	Category	Installed (8)	Considered (8)	Not considered
Ownership	Multi-national (10)	14	6	0
	Domestic (10)	7	3	3
Size	Medium/medium production (10)	11	2	3
	Large scale production (10)	10	7	0
Temporal profile	Continuous (10)	18	9	2
	Batch (10)	3	0	1
	TOTALS	**21**	**9**	**3**

These criteria and associated categories were designed to ensure that the sample covered significant range and diversity in terms of the knowledge, understand and experience of heat recovery. Each criterion had a specific rationale for inclusion:

- **Stages of heat recovery technology implementation:** as this research is attitudinal and behavioural, we determined that the distinction should be made between those who had recently implemented heat recovery and those who had considering doing so. Those who had not considered were determined to be of less interest, as they had much narrower views around barriers, and are incorporated but with no minimum target has been set.
- **Size of industrial facility** (relative to size of others within their industry): was incorporated to act as an appropriate metric of approximate size of business, and energy usage.
- **Type of industrial process** (continuous or batch production): continuous processes are generally more useful in recovering heat, and easier to predict the outcomes from this; whilst batch process can present more technical and commercial challenges. This is useful as a sampling criteria to help understand the extent to which this impacts attitudes and behaviours, as well as helping to ensure a range of companies are involved with different types of industrial processes.
- **Corporate ownership location** (domestic or multinational): this was determined to be a potentially important distinction in financial and other motivations towards heat recovery.
- **Sector**: to ensure that a good cross section of UK energy intensive industries are engaged.

While the study has uncovered a range and diversity of experiences, the analytical value of some criteria as originally designed is limited. Homogeneity of process was not as instructive as process complexity or company characteristics; whether or not companies had installed heat recovery technologies was a less useful distinction as some technologies are installed as part of business as usual in some industries and are therefore present throughout.

Although quotas were set for these primary sample characteristics, we also monitored the sample to ensure that all energy intensive industries were represented. Table 6.2 below illustrates the sample achieved for each industry.

Table 6.2: Achieved sample – industry

Industry	Number of interviews
Glass (3)	5
Food & Drink (3)	5
Iron & Steel (3)	3
Cement (3)	4
Chemicals (3)	9
Ceramics (3)	4
Paper & Pulp (3)	3
Oil Refining[13]	0
TOTAL	**33**

Recruitment

In qualitative research, where there is not a ready-made named sample frame from which to draw your sample, a range of methods are available. As these alternative methods all have their own biases, our approach to this study was to use a combination of approaches. We used a three main sources to generate this sample:

- Existing contacts held by Madano and Element Energy;
- Working with gatekeepers, the Trade Associations, to access their members
- Generating our own sample frame through publicly available lists and internet searches

Once identified, potential participants were contacted initially by phone or email and provided with information on the background to the research and what their participation would entail. They were then asked if they were interested in taking part. A short screening interview was carried out those opting-in in order to identify sample characteristics and whether a face to face or telephone interview should be carried out (where participants had very little knowledge of heat recovery, interviews were conducted over the telephone). Arrangements were then made for a full interview to take place at a convenient time.

[13] Note that the Oil Industry companies were not able to take part in this study.

Data collection

Interviews adopted a **socio-technical approach.** This combined the technical knowledge of Element Energy and social research expertise of Madano. This was crucial to ensure that the data collected was sufficiently technical but also included a consideration of social, cultural and institutional issues best uncovered through social research interviewing techniques. To blend together these skills, a number of activities were carried out:

- Prior to the start of fieldwork a **full interviewer briefing** was carried out. Experts from Element Energy provided researchers with a background to heat recovery, an understanding of how this might work in different industries and in relation to different processes. A walk through of the topic guide and possible responses was also carried out.
- The **first six interviews were conducted in pairs**, with a technical experts from Element Energy accompanying Madano researchers to enable researchers to use their qualitative skills to elicit depth and detail but to be guided by technical experts as to the nature of that probing. Small revisions were made to the interview discussion guide following these interviews.
- A number of **stimulus materials** were used as part of the interview process. These included standard process diagrams to help assess participant knowledge of heat loss and possible heat demand. Interviewees were also asked to explain their 'heat recovery journey' from identification to installation, by explaining how their journey different or adhered to a loose visual structure of a typical journey developed by the research team.

The majority of interviews took place face to face, providing the opportunity to view site lay outs and equipment where necessary. Where interviewees were found to have limited knowledge of heat recovery through the screening process, interviews took place over the telephone. Interviews lasted between 25 and 90 minutes and were conducted between 4th March and 12th May. Interviews were digitally recorded and transcribed for full analysis.

Analysis

Data from interview transcripts was managed using the Framework method, a widely used approach for social policy research. The approach generates summarised matrices of data, ensuring a systematic, comprehensive and transparent approach to analysis. These outputs are then used as the raw material for detailed thematic and case-based analysis. Our analysis of this data set focused on identifying emerging themes and points of difference between participants in relation to the key research questions. This approach has enabled us to address the research objectives in detail and identify nuanced differences between participants, or types of participant, and provide explanations for these differences.

Annex A – Energy Team typology

The organisational factors motivating companies to be energy efficient, described in the previous section, encourage companies to manage and monitor energy efficiency in different ways. This section describes the different structures and approaches adopted by companies participating in this study for managing and monitoring energy efficiency. Across our sample of 33 companies, the staff responsible for energy management and improving energy efficiency were structured in five ways, set out in Table A.1 below.

Table A.1 Team structures and approaches to energy management

	Team Structure	Approach to energy management
Multi-person teams	**Dedicated energy teams:** staff devoted to energy management and efficiency	Comprehensive, sophisticated and proceduralised monitoring on a continuous basis for each part of the process. Commercially driven.
	Disparate teams: individuals from across other departments or across sites	Sophisticated daily monitoring across process as whole, some highly proceduralised. Commercial drivers compete with corporate drivers.
	Non-dedicated teams: teams with other responsibilities	Ad hoc monitoring across process as whole. Corporate drivers dominate.
Single individual	**Dedicated individuals** whose role is devoted to energy management and efficiency	Some sophisticated daily monitoring across process as whole, others ad hoc. Commercial drivers compete with corporate drivers.
	Non-dedicated individuals who also have other responsibilities	Ad hoc monitoring across process as whole. Corporate drivers dominate

Dedicated energy teams

Dedicated energy teams comprise multiple staff devoted to energy management and efficiency across all sites and processes. These teams have comprehensive, sophisticated and proceduralised monitoring for each part of the process. Their performances is typically assessed by input-driven KPI's – that is the resources they use rather than the products they produce. This approach was seen as essential to meeting stringent, self-imposed energy targets that were often over and above regulatory requirements in order to stay in business.

Companies with dedicated teams are large, multinational organisations with a turnover of over $1bn. They are *super energy intensive* companies with energy accounting for between 50% and 76% of their total operating costs. In this study, these companies are drawn exclusively from the chemicals and cement industries.

Approach to energy management: The products of these companies are highly commoditised and their performance is assessed by input-driven KPIs – that is the resources they use, rather than the product they produce. As such, they typically engage in few other business activities that are client facing. Participants described energy as *'one of our core business activities'* and embedded in the role of each member of staff.

> *'Energy is such an important part of the business that it can't possibly be one person's job; it has to be everyone's'*

(Large, multinational company with dedicated energy team)

The monitoring of energy is highly 'proceduralised', supported by sophisticated monitoring and modelling technology that provides minute-by-minute, around the clock updates on energy consumption and process optimisation.

> *'On a daily basis we are reporting the previous day's efficiency. We've got live display of that information on each plant, on the main [product] plants, which are by far the biggest gas consumers, and so we've got daily reporting of that, and a monthly reconciliation of that.'*

(Large, multinational company with dedicated energy team)

The approach to identifying inefficiencies in their processes was demonstrably systematic. Participants described this as essential to meeting stringent, self-imposed energy targets that were often over and above regulatory requirements in order to stay in business. These teams are able to identify efficiencies across sites in a co-ordinated way, avoiding sub-optimal site competition or sites acting in isolation.

> *'The [dedicated team] has been here probably about ten years. Before that the sites were managed individually…If one site had a good idea then there was always a bit of competition between the sites…and tension between identifying best practice and then implementing it elsewhere. [What we have] done kills all that because it brings everything into one centre. You've got one manager responsible for the lot. So if he identifies best practice on one plant we just do it and there's none of that politics of "I don't agree with that, I don't want to do that". There's a set of common data, set of facts and we just do it.'*

(Large, multinational company with dedicated energy team)

Staff characteristics and responsibilities: Dedicated energy teams comprise at least three members of staff, devoted to monitoring the consumption of energy across the entire company. Individuals in these roles typically have an engineering background. The teams have total responsibility for energy management across all processes and sites operated by their company. They also have a responsibility for encouraging behaviour change throughout the organisation to improve energy efficiency, although this is of secondary importance. The teams are responsible for regulatory requirements, but this typically happens as a consequence of 'business as usual' activities.

Disparate energy teams

The disparate teams in our sample comprise a group of people brought together from across departments or sites, with roles not always exclusively devoted to energy. These companies' processes are not as highly commoditised as products produced by companies with dedicated teams but are typically mass produced rather than bespoke. Performance is assessed on the basis of a mixture of input- and output-driven KPIs. They engage in sophisticated daily monitoring across their processes, in some cases in some highly proceduralised way.

These companies are often operate multiple sites or employ large numbers of staff, though they have a wider turnover range than companies with dedicated energy teams. Energy is important, accounting for up to 25% of total costs. The corporate functions of these companies are also diverse and some of the companies are well-known consumer brands from across the seven energy intensive industries included in this study.

Approach to energy management: These companies produce various products, which are not as highly commoditised as products produced by companies with dedicated teams but are typically mass produced rather than bespoke. Performance is assessed on the basis of a mixture of input- and output-driven KPIs. As a result, in some cases, disparate energy teams share much in common with the dedicated teams in seeing energy efficiency as a crucial if not core part of their business. Where energy represents a higher proportion of a company's total costs they monitor consumption extensively and understand well the inefficiencies in their process.

> *'We use a metric which is kilowatt hours per thousand kilos. So it's about improving the efficiency, reducing the amount of kilowatt hours to produce a thousand kilos'*
>
> (Large, domestic company with disparate energy team)

Their approach is, however, less proceduralised: it is not as frequent or systematic and their understanding of consumption is on a daily or weekly basis rather than real-time and around the clock. This means their ability to identify inefficiencies is more limited.

Staff characteristics and responsibilities: These teams are disparate in one of two ways: they draw in people from across different departments such as technical departments, contracts and legal, procurement and human resources; or they draw together technical staff from across multiple sites. As energy is seen more as one of many corporate functions rather than a core activity, these staff have a wider range of career expertise beyond engineering, as illustrated by the exchange between two colleagues below:

> *Participant 1: Although I'm contracts manager, I also head-up a renewable energy team for the business… My background was the building products business*
>
> *Participant 2: I'm a co-opted member of [participant 1's] renewable energy group as well…my current role as chief manager in [company location], which is basically where all the plants are, but my background is 25 years in environment management*

(Medium, multinational company with disparate energy team)

These teams typically have a wider set of responsibilities than the dedicated energy teams, including engaging with staff, customers and suppliers around behaviour change and encouraging a culture of sustainability within the company.

> *Some of the staff surveys [show] that people work for [company name] and feel proud to work for [company name] because they're part of an organisation that is striving to improve or reduce its energy use. So our job is very much that soft cultural part of it.*

(Large, multinational company with disparate energy team)

These teams are also heavily involved in regulatory compliance and their actions are sometimes driven specifically by this.

Non-dedicated teams

These are coherent teams of people, but chiefly dedicated to a different area of the business with energy an additional responsibility. The products these companies produce are not commodities and in some cases highly bespoke. KPIs, where they exist, therefore relate to the specifications of the product. Monitoring of energy usage and efficiency was described as taking place in an ad hoc fashion, rather than systematic or proceduralised.

This group represents a very small number of the companies in our sample; as such there is more limited detail and diversity contained in the description. The companies in this group are medium in size and drawn from the Glass and Cement sectors, however it is likely that such teams exist in other sectors, particularly Food & Drink and Ceramics.

Approach to energy management: The products these companies produce are not commodities and in some cases highly bespoke. KPIs, where they exist, therefore relate to the specifications of the product. Energy is a significant cost to these companies, but as a business priority energy efficiency is one of a number of other strategic priorities. The approach to energy management, therefore, has most in common with smaller organisations with disparate teams. They take steps to monitor consumption and are '*on the lookout'* for energy efficiency projects but do not have a proceduralised approach or a comprehensive understanding of the nature of inefficiencies in their processes.

Staff characteristics and responsibilities: The main focus of the work of these teams was either contracts and compliance, or environment, health and safety.

> *'I lead the sustainability forum within compliance…I report in to the industrial director for most things, but for big investments I would report more directly to the COO… our procurement manager deals a lot of the paperwork for because we sit under the CCA…we have two people doing CCA and CRC, and then also have the environment manager, or health safety and environment manager.'*

(Large, domestic company with non-dedicated energy team)

It is conceivable that other teams could also take on these responsibilities in other companies not included in our sample. As a result, the individuals in these teams have a range of skills and experience but no engineering background or little experience in an energy-specific role. Teams are typically driven by a need to satisfy health and safety requirements or a corporate objective to encourage more sustainable working practices, not just in the industrial processes they operate but across the business as a whole.

A dedicated individual

A dedicated individual describes a single member of staff devoted entirely to energy management across the company. Companies with a dedicated individual managing energy produce less commoditised, but not entirely bespoke, products. Key Performance Indicators (KPIs) are related to production or output and not efficiency or carbon targets. They focus exclusively on monitoring consumption, identifying efficiencies and achieving certain standards but do ot have the resource to be as systematic as dedicated teams.

Dedicated individuals are typically found in smaller companies (in terms of revenue) some of whom are consumer-facing. Energy is very important to these organisations and a high proportion of their costs (up to 20%). The dedicated individual approach is found across the energy intensive sectors involved in this study, apart from Cement and Iron & Steel.

Approach to energy management: Companies with a dedicated individual managing energy produce less commoditised, but not entirely bespoke, products. Key Performance Indicators (KPIs) are related to production or output and not efficiency or carbon targets. The employment of a dedicated individual reflects the fact that energy is important to these companies. In this respect the dedicated individual has a lot in common with dedicated teams. They focus exclusively on monitoring consumption, identifying efficiencies and achieving certain standards.

> *'I am the energy manager within the UK's group engineering function. My role is to implement our energy management system, which we're currently having certified to 50001, and to advise our manufacturing sites and help them to develop technical solutions to energy management issues across all the fields of energy management and efficiency.'*
>
> (Large, multinational company with dedicated individual)

These companies aim to provide a comprehensive understanding of the efficiency of their plants, but their overall turnover and other priorities precludes them from employing more than one individual. Their approach to energy management is not, as a result, as proceduralised and sophisticated as the dedicated teams. They do not have the resources of dedicated teams and therefore do not have the systematic infrastructure in place to fully optimise processes and identify opportunities for greater efficiency. These companies are also influenced by regulators and compliance requirements, which are considered more overtly than in companies with dedicated teams, where the business as usual approach meets regulatory requirements by default.

Staff characteristics: These dedicated individuals are energy experts typically from an engineering or technical background.

> *'I'm technical and environmental manager…I started as technical apprentice many moons ago, and have done such jobs as site quality controller, furnace manager, production manager, and now technical and environmental manager.'*

(Small, domestic company with dedicated individual)

They are sometimes part of technical teams or compliance teams where these exist, or in small organisations they report directly to a technical director or the managing director, who is involved in sign-off and decision making for energy efficiency initiatives. Their knowledge of heat recovery opportunities is varied, seemingly determined by their previous experience rather than requirements of their current role.

Non-dedicated individual

A non-dedicated individual describes a single person with responsibility for energy management who also has one or more other unrelated responsibilities. These companies produce a narrow range of products, in some cases bespoke and high-end products produced in made-to-order batches. Energy is less of a priority and the approach of these companies to energy management was therefore typically *ad hoc*. This was because it was of secondary importance compared to other priorities or because staff were constrained by a lack of resource or expertise

Typically, these companies are smaller compared to the rest of the sample and all are small relative to their industry, though some are multi-national. Non-dedicated individuals were identified in companies cutting across all the industries included in this study, apart from Cement.

Approach to energy management: These companies produce a narrow range of products, in some cases bespoke and high-end products produced in made-to-order batches. While energy is described as important by participants from some of these companies, this had not translated into employing a dedicated individual and they have no formal KPIs or other targets related to energy consumption or efficiency. The approach of these companies to energy management was therefore typically *ad hoc*. This was because it was of secondary importance compared to other priorities or because staff were constrained by a lack of resource or expertise.

> *'There isn't a team. We're only a small company. It's just me. We have monthly management meetings and that's when the managing director will be down, and it's attended by the chairman. I will put forward ideas…then take them to meeting, or would take them to the meeting and say, 'Can we look into this, investigate that?' and we sort of develop it.'*

(Small, domestic company with non-dedicated individual)

Non-dedicated individuals monitored energy as part of a whole range of other day-to-day responsibilities and priorities. This did not mean, however, that no energy efficiency initiatives took place. Technical managers who understood their processes described having made a good case directly to a company owner who signed off efficiency improvements immediately. Similarly, Managing Directors and owners themselves who take responsibility for energy management may wish to ‘Champion’ sustainability within the company, or may have a specific personal interest in a particularly technology.

Staff characteristics and responsibilities: Non-dedicated individuals occupy a wide range of other roles, of which energy is often a small part. In some cases, the non-dedicated individual was one of only three to five people employed on the whole site. Expertise was typically limited in this group, except where a Managing Director or Site Director was a former engineer that had set up their own company or partnership.

> *‘I'm the managing director for [company name]. My previous companies have been much larger so there would be energy departments and technical people in abundance, whereas this is a small single site business…One of the key elements of the costs is the gas cost and therefore one of my key roles is to try and reduce that as much as we can.’*

(Medium-sized, domestic company with non-dedicated individual)

The responsibilities of non-dedicated individuals are comparatively limited. While they do what they can to monitor consumption and identify efficiencies, participants did not typically describe staff engagement or behaviour change projects, though it is likely that this is also a function of the size of the organisations.

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