Applied Energy 116 (2014) 387–397

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

# Heat recovery opportunities in UK industry

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## HIGHLIGHTS

- Heat recovery opportunities from UK industry were evaluated.
- Surplus heat availability was based on previous work.
- Various technologies to utilise the recovered heat were examined.
- Greatest potential shown for heat use on-site and its conversion to electricity.
- Transportation of heat shows potential, but will require the existence of networks.

## ARTICLE INFO

*Article history:*
Received 25 September 2012
Received in revised form 21 October 2013
Accepted 3 November 2013
Available online 28 November 2013

*Keywords:*
Heat recovery
Industry
Manufacturing
United Kingdom
Waste heat
Surplus heat

## ABSTRACT

A database of the heat demand, and surplus heat available, at United Kingdom industrial sites involved in the European Union Emissions Trading System, was used to estimate the technical potential of various heat recovery technologies. The options considered were recovery for use on-site, using heat exchangers; upgrading the heat to a higher temperature, using heat pumps; conversion of the heat energy to fulfill a chilling demand, using absorption chillers; conversion of the heat energy to electrical energy, using Rankine cycles; and transport of the heat to fulfill an off-site heat demand. A broad analysis of this type, which investigates a large number of sites, cannot accurately identify site level opportunities. However the analysis can provide an indicative assessment of the overall potential for different technologies. The greatest potential for reusing this surplus heat was found to be recovery at low temperatures, utilising heat exchangers; and in conversion to electricity, mostly using organic Rankine cycle technology. Both these technologies exist in commercial applications, but are not well established, support for their development and installation could increase their use. The overall surplus heat that was technically recoverable using a combination of these technologies was estimated at 52PJ/yr, saving 2.2Mt$CO_{2e}$/yr in comparison to supplying the energy outputs in a conventional manner. It is thought that a network and market for trading in heat and the wider use of district heating systems could open considerable potential for exporting heat from industrial sites to other users.



## 1. Introduction

The United Kingdom (UK) industrial sector is responsible for approximately 20% of the UK's final user energy demand [1], the vast majority of this energy is supplied through fossil fuels, either directly, or indirectly through electricity use. Emissions of greenhouse gases (GHGs), primarily carbon dioxide, are associated with the use of this fossil fuel, the reduction of these emissions is required to meet government targets, such as an 80% reduction in emissions by 2050, on 1990 levels [2]. Such emissions can be reduced by either decreasing the energy demand or supplying the demand in a less carbon intensive way. For the companies that comprise the industrial sector the requirement to meet legislation designed to reduce energy demand and carbon emissions (such as the EU ETS, CRC and CCAs), alongside the increasing costs of energy [3], should represent strong drivers to reducing energy demand.

Heat is responsible for approximately 70% of final energy demand in UK industry [4]. All heating processes result in a surplus of heat energy at the end of the process [5]. This surplus heat source[1] can, in certain cases, be recovered and utilised to fulfill an existing energy demand. Using surplus heat in this manner would replace conventional energy sources, and so reduce both energy costs and associated emissions. Heat recovery is commonly practiced in manufacturing, especially in energy-intensive industries, although

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[1] Also commonly referred to as a waste heat source. The term surplus heat source is used throughout to avoid confusion.

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http://dx.doi.org/10.1016/j.apenergy.2013.11.008

**Nomenclature**

*Abbreviation*

| | |
|---|---|
| EU ETS | European Union Emissions Trading System |
| NAP | National Allocation Plan |
| CHP | Combined Heat and Power |
| CRC | Carbon Reduction Commitment |
| CCAs | Climate Change Agreements |
| GHG | Greenhouse Gas |
| COP | Coefficient of Performance |
| ORC | Organic Rankine Cycle |

*Symbols*

| | |
|---|---|
| $\eta$ | energy efficiency |
| $T$ | temperature (K) |

*Subscript*

| | |
|---|---|
| 0 | sink (environment) |
| $P$ | source (process) |
| $D$ | delivered |

it is thought that considerable potential still exists. The UK Government's Office of Climate Change estimated annual surplus heat recovery potential in UK industry at 18TWh (65PJ) in 2008 [6]. McKenna and Norman [7] subsequently estimated the surplus heat that could technically be recovered from those sites in the European Union Emissions Trading System (EU ETS) as 36-71PJ/yr. An end use for the surplus heat was not specified. The assessment by McKenna and Norman [7] and that by the UK Government's Office of Climate Change [6] were both based on conservative estimates and considerable uncertainty.

The aim of the current paper was to identify a use for the technically recoverable surplus heat identified by McKenna and Norman [7]. The objectives adopted to achieve this aim were:

1. To determine the required characteristics of a surplus heat source for it to be utilised through each of the examined heat recovery technologies. Further to identify the required characteristics of a suitable demand.
2. To assess the potential for the identified surplus heat sources to be utilised by the examined technologies under two scenarios:
   a. All surplus heat sources were available for use by each of the technologies.
   b. The technology (or technologies) that was applied to each surplus heat source was chosen to maximise a desired saving (e.g. GHG emissions).
3. To discuss the results within wider knowledge.

The technologies assessed for utilising surplus heat sources were:

- On-site heat recovery, to fulfill a lower temperature demand, through heat exchanger networks or similar.
- Upgrading the surplus heat for use at a higher temperature, using heat pumps.
- Conversion of surplus heat to chilling energy, using absorption heat pumps.
- Conversion of surplus heat to electricity, using Rankine cycles.
- The transportation of heat, to fulfill an offsite heat demand.

The choice of technologies was based on the previously successful adoption of such technologies in utilising surplus heat sources within industry, and the availability of relevant information to allow an analysis of the technology. Due to the uncertainties surrounding the estimation of surplus heat availability, and technology performance when assessing opportunities on a broad scale, the analysis was intended to provide an indicative estimation of the potential. The analysis would not be expected to be accurate at a site level, but was conducted to indicate the scale of opportunities for different technologies, and to provide a basis for further, more detailed, analysis.

## 2. Methodology

### 2.1. Dataset

The dataset used here was built on previous work [7]. Each site within the Phase II UK National Allocation Plan (NAP) of the EU ETS was classified into one of thirty-three subsectors. Information on the processes undertaken within these subsectors was used in conjunction with emissions or output data at the site level to estimate heat demand and the technically recoverable surplus heat. Heat demand was estimated in five temperature bands (less than 100 °C, 100–500 °C, 500–1000 °C, 1000–1500 °C and over 1500 °C). For each site the temperature and magnitude of a single surplus heat source was estimated. Due to the uncertainties involved in estimating the surplus heat recoverable, a range was applied to the magnitude of each surplus heat source [7]. The methodology adopted in the current work differs slightly from that used previously [7]. Formerly only fuel use was assumed to contribute to heating demands, with the exception of subsectors where it was known the majority of heating was supplied by electricity (for example, in electric arc furnaces) [7]. In the current work a proportion of electricity demand at all sites was assigned to heating processes, this proportion was based on available data for the UK [4]. Any heat demand currently fulfilled by CHP plants was removed in the current work. As this demand was already met in an energy efficient manner, it was not felt appropriate to replace it with surplus heat. There were a total of 425 sites included in the analysis. The data used refers to the time period from 2000–2004 with the heat demand and surplus heat available based on the mean emissions recorded in these years (with the highest and lowest values removed). This assessment covered approximately 60% of total industry and 90% of energy-intensive industry energy demand [7]. Energy demand in UK industry since this period has reduced, due in part to the economic recession experienced in the UK. Energy demand fell by 20% between 2004 and 2010, with the majority of this drop occurring during 2008–2009 [8]. Some large users of energy ceased operations over this period, e.g., the Teesside integrated iron and steel works was mothballed in February 2010 [9]. However, the plant has since changed ownership [10], and the blast furnace was relit in April 2012 [11]. Additionally two of three UK aluminium smelters were closed, or their closure was planned [12,13]. Likewise closures have occurred in the Cement and Pulp and Paper subsectors. The long-term future of these plants, and how much capacity other plants may change in response, is uncertain. The information presented here was unaltered from that over the 2000–2004 period.