Energy 151 (2018) 430–441

Contents lists available at ScienceDirect

Energy

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

Risk assessment of industrial excess heat recovery in district heating systems

Kristina Lygnerud*, Sven Werner

Halmstad University, PO Box 823, SE-30118, Halmstad, Sweden

ARTICLE INFO

Article history:
Available online 10 March 2018

Keywords:
District heating
Excess heat recovery
Risk assessment
Sweden

ABSTRACT

The recovery of industrial excess heat for use in district heating systems can be characterised by great political interest, high potential, low utilisation and often high profitability. These characteristics reveal that barriers are present for its greater utilisation. One identified barrier is the risk that industries with excess heat can terminate their activities, resulting in the loss of heat recovery. Excess heat recovery investments are therefore sometimes rejected, despite them being viable investments. The risk of termination of industrial activities has been assessed by a study of 107 excess heat recoveries in Sweden. The analysis verified that terminated industrial activities are one of two major explanations for terminated heat delivery. The other major reason is substitution by another heat supply. These two explanations correspond to approximately 6% of all annual average heat recoveries. The identified risk factors are small annual heat recovery and the use of heat pumps when low-temperature heat was recovered. The main conclusion is that a small proportion of industrial heat recovery has been lost in Sweden because of terminated industrial activities. The risk premium of losing industrial heat recovery for this specific reason should be considered to be lower than often presumed in feasibility studies.

1. Introduction

1.1. International context

District heating companies provide heat to consumers through heat distribution networks. The heat supplied is mainly recycled from external activities, such as thermal power generation, waste incineration and energy-intensive industrial processes. The fundamental business idea is simply to reuse existing heat sources [1]. This reuse of heat is complemented with direct heat generated by boilers or large heat pumps. Internationally, the most common form of heat supply to district heating systems is in synergy with thermal power generation [2], when heat is supplied from combined heat and power (CHP) plants. Most of these CHP plants still use fossil fuels, however. With respect to lower emissions of carbon dioxide, this fossil-based heat recovery should be substituted with a combination of renewables and further heat recoveries, such as recovery from industrial excess heat.

This possible reuse of existing excess heat streams has been identified by the European Commission: “In its 2016 impact assessments for the reviews of the Energy Performance in Buildings Directive, the Energy Efficiency Directive, the Renewable Energy Directive and for the new Market Design Initiative, the Commission will analyse different options to help buildings and industry shift to efficient, decarbonised energy systems based on renewable energy sources and the use of waste heat” [3]. The background to this heightened political interest is that industrial excess heat recovery can contribute to overcoming the energy efficiency gap, i.e., the gap between identified cost-efficient energy efficiency measures and their implementation rates [4]. By closing the energy efficiency gap, primary energy would be saved, greenhouse gas emissions would be reduced, and heat could be utilised that otherwise would be lost.

The potential for industrial heat recovery is high in Europe. According to a survey of various estimated potentials for different countries [5], the EU technical potential, without any restrictions, could be 2.7 EJ/year. This corresponds to about one-quarter of the European heat demands for buildings of about 10 EJ/year [2]. It is known that the most suitable heat to be recovered comes from industrial sites having excess heat from high-temperature processes [6]. A systematic heat cascading concept for an integrated industrial-urban system was presented in Ref. [7]. Internationally, the high potential for further use of industrial excess heat in district

* Corresponding author.
E-mail addresses: kristina.lygnerud@hh.se (K. Lygnerud), sven.werner@hh.se (S. Werner).

https://doi.org/10.1016/j.energy.2018.03.047
0360-5442/

heating systems has been verified and assessed for the United Kingdom [8], Spain [9], Germany [10,11], Denmark [12], China [13–15] and the European Union [16,17].

The current utilisation of recovered industrial heat is low, compared to the total heat supply in national district heating sectors. A brief survey is provided in Table 1 for some countries with developed district heating systems. This information was mainly obtained from national sources from Denmark [18], Finland [19], France [20], Germany [21], Russia [22] and Sweden (this study), since the International Energy Agency energy balances do not report these heat supplies properly because these regular energy balances do not track heat deliveries between different end-user groups. The total volume of industrial heat recovery in the EU can be estimated at about 30 PJ/year, which is about 1% of the full technical potential reported in Ref. [5].

In the literature, some studies have indicated the typical static payback periods for industrial excess heat recovery investments, concerning connections to existing district heating networks. Interviews with some Swedish industrial companies in Ref. [4] revealed payback periods of one to three years for excess heat recovery investments. The connection of the second oil refinery in Gothenburg, Sweden in 1997 was reported in the local newspaper as having a total payback period of about four years [23]. One plate-exchanger manufacturer communicated the case story of Helsingborg, Sweden as an example of a successful industrial heat recovery. This cooperation initially had an overall payback period of less than one year [24]. A recent UK study estimated that some initial industrial heat recoveries could be commercially implemented with payback periods of less than two years [25]. An Italian case study of a small industrial heat recovery was reported as having a payback period of five years [26]. A recent paper [27] reported that payback periods of around three years could be achieved for a number of cases concerning a petrochemical cluster in Stenungsund, Sweden.

These payback periods for industrial excess heat recovery investments do not appear to be substantially longer than for other alternative investments in energy supply. An indicative conclusion is that most suitable industrial excess heat recoveries could be connected to existing district heating systems with payback periods of between one and seven years; however, shorter payback periods should be expected in countries with developed policy instruments for the substitution of fossil fuels, such as carbon taxes or emissions trading.

Internationally, the identified combination of high potential, low utilisation and often high profitability reveals that major barriers exist for investment in excess heat recovery.

1.2. Current knowledge concerning barriers to industrial excess heat recovery

Barriers to industrial excess heat recovery investments have been identified in several scientific articles and reports. Barriers external to the investment decision are the absence of a district heating network, cost-competitive heat supply alternatives, and current policy incentives for other forms of heat supply, such as bio- or waste-fuelled CHP plants [4,28–32].

Barriers to making the investment decision are many, and their assessment is complex. The technical circumstances of the investment are sometimes linked to the barriers. Examples are technical solutions that are more complex than were foreseen, profit erosion from too low temperature levels of the excess heat [29] and too costly transmission pipes [4,28–30]. Other barriers are less tangible, and are linked to the interaction between the local district heating company and the excess heat provider.

The provider and the district heating company often hold different views of the quality of the excess heat. The industry tends to claim that the available heat is of premium quality, which should be reflected in the price, whilst the district heating company may disagree. Another level of complexity concerning excess heat recovery investments is the asymmetric information about the inputs and outputs of each party in the collaboration [4,33]. Furthermore, to arrive at a profitable excess heat recovery investment, energy efficiency competency from the district heating company and the excess heat provider is imperative [28,34], as are shared incentives., Split incentives, when implementing energy efficiency measures, are common, however [30]. Finally, the investment in excess heat recovery competes with alternative uses for investment capital [4,31,32,35].

Apart from the external barriers to excess heat investments, and barriers to arriving at an efficient investment decision, there is one important additional barrier often mentioned. That is the risk that the excess heat provider will terminate its industrial activities. In one study [4], several respondents addressed the risk of reduced heat availability because of the industry shutting down, relocating, or modifying the local production process that creates the excess heat. The risk of closure of the industry was also mentioned as a key factor in a study of factors that promote or inhibit district heating collaborations between industry and utilities [30]. A reduced risk was presented in Ref. [36], wherein heat recovery cooperation can actually offset, or at least reduce, the risk of a company closing down, since remuneration for the recovered heat can become an additional revenue stream to support the industrial process.

The external barriers, and barriers linked to the investment decision mentioned above, can rationally be accounted for in the investment decision by adding a risk premium. The barriers can be contrasted with the benefits of the excess heat recovery investments for the district heating company in terms of reduced carbon dioxide emissions, less need to provide capital in fixed assets (the excess heat recovery investment is often less capital intensive than alternative heat supplies), and a local partnership with the excess heat provider. The cognition of risk associated with the excess heat provider going out of business is difficult to quantify in an objective manner, however. No scientific information is currently available about how high this termination risk is, or why the transfer of recovered excess heat into district heating systems is terminated. Consequently, the risk premium in investment assessments is somewhat exaggerated, due to this uncertainty.

1.3. Research questions

In this study, a novel analysis has been provided for estimating the magnitude of the risk associated with termination of industrial excess heat deliveries. Industrial excess heat recovery investments are built on the rationale of a synergy that creates an economic win-win situation between the excess heat provider and the district heating company. The risk of terminated industrial excess heat

Table 1
Survey of annual volumes of recovered industrial excess heat supplied to national district heating sectors during 2014, and the corresponding proportions of the heat supply to these national district heating sectors. Sources for this information are referenced in the text.

	Industrial heat recovery, PJ	Proportion of total heat supply
Denmark	2.6	2.1%
Finland	2.9	2.3%
France	2.2	2.4%
Germany	4.0	1.6%
Russia	330.8	6.0%
Sweden	17.8	9.0%