Integration of Low Grade Heat with District Heating

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Large quantities of low grade heat with temperature ranging from 30 °C to 250 °C as liquids (cooling water) and gases (flue gas) is not utilized across process industry. This heat can reduce the energy consumption for district heating (DH) and therefore reduce the carbon footprint for the integrated system. The techno-economic feasibility of over the fence process integration of low grade heat with district heating network is evaluated in this work. The quantity of available low grade heat is determined by total site integration tools. The feasible distance of transfer between the source of low grade heat and the district heating network is calculated based on the cost of district heating supply and network design cost. The methodology shows that the economic benefit of integration of low grade heat with DH is dependent on the case study.

1. Introduction

The energy demand for heating homes, business complexes, and industry accounts for 49 % of the total energy demand and 47% of the total carbon emissions (Davies and Woods 2009). Waste heat of limited use can be utilized by district heating (DH) networks. District heating design consists of a system for central production of heat. Heat is transferred to individual houses or buildings as hot water by pipes. District heating has the potential to increase the efficiency of energy use and reduce carbon emissions, by CHP, integration of renewable energy sources, waste heat and biomass (Holmgren 2006). The cost of heat distribution including network costs and operating costs to compensate for high temperature and pressure is the main cost for DH in comparison of local heat generation (Persson and Werner 2011).

Large amount of low grade heat is available across process industry. The opportunity includes the waste heat recovery from liquids and gases, combined heat and power, drying, steam generation and consumption, and waste heat utilization. Low grade heat recovery is highly relevant in the field of chemical, petroleum, forest products, food processing, manufacturing, iron and steel, and cement. The quantity of low grade heat produced is determined by the existing methodology for the total site integration (Klemeš et al. 1997; Smith 2005). The feasibility of integration of low grade heat to the district heating network is dependent on the distance of the district heating production centre to the source of low grade heat, the variability of the available low grade heat

during different seasons and the price of heat. The district heating demand is variable according to the time of the day, season, and day in the week. The heat producing equipments for a district heating network are usually run at part load performance during different time of the day. The integration of low grade heat from process industry changes the part load of the energy equipment and therefore integration of low grade heat provides additional complexity in terms of cost of an existing district heating network.

2. Case Study

2.1 Industrial site data – source of waste heat supply

The techno economic analysis of the feasibility of over-the-fence process integration is evaluated with the help of a case study. The total site sink and source profile for the given case study is shown in Figure 1. Steam demand at VHP, HP, MP and LP levels are 110.8, 21.4, 9.3 and 73.6 MW respectively. Power generation potential is represented as areas in SUGCC with VHP-HP, HP-MP and MP-LP cogeneration potential of 79.8, 58.4 and 49.1 MW.
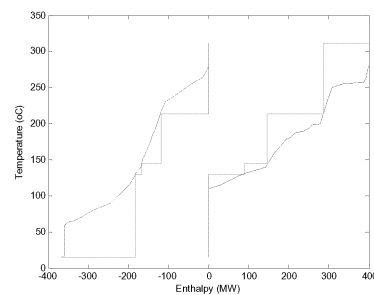

Figure 1: Site source and sink composite curve

The amount of low grade available at a temperature higher than 105°C is shown in Figure 2 is 62.11 MW. Site source profile below 105°C is shifted by 62.11 MW to account for the extraction of low grade energy and hence the CW requirement for the total site decreases by 62.11 MW.
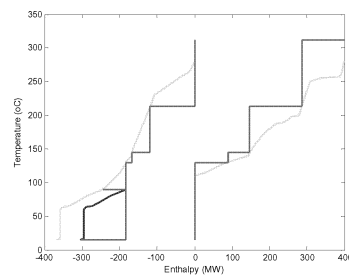

Figure 2: Low grade heat available from the site profiles

2.2 District heating (DH) system

The existing district heating supply framework consists of two CHP plants; alternative waste and oil CHP and mixed fuel CHP. The system consists of two boilers; waste fired and oil boiler. The detailed performance data for the four units on the supply side for Linkoping network is shown in Table 1 (Rolfsman 2004).

Table 1: Existing plant data in Linkoping (Rolfsman 2004).

Plant	Heat (MW)	Electricity (MW)	Fuel Price ($/MWh)	Efficiency	Electricity / heat ratio
Waste boiler	80	-	-11.25	0.9	-
Oil boiler	360	-	51.9	0.85	-
Alt. waste and oil CHP	90	47	7.2	0.82	0.52
Mixed Fuel CHP	201	59	26.7	0.92	0.29

Demand data is required to evaluate the performance of the DH system before and after integration of waste heat. Figure 3 shows a demand duration profile for a DH system with total heat demand of 1.22 TWh/y. The DH system has a maximum winter load of 175 MW and a minimum load of 133 MW in summer.
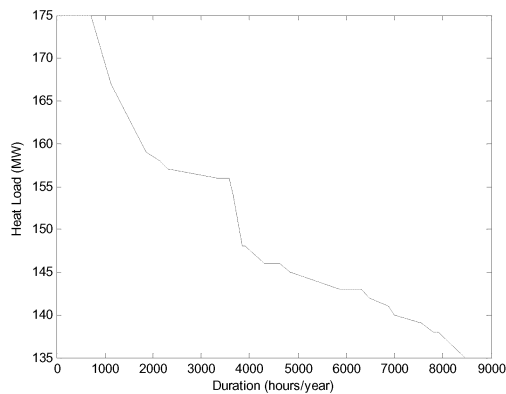

Figure 3: DH system demand duration profile

3. Methodology

The total site composite curves are obtained from the data given by Aguillar (2005). Low grade heat available on site is obtained from the composite curve. District heating network case study presented in this work for Linkoping in Sweden (Rolfsman 2004).

Integration of waste heat with district heating reduces the load on the boiler and CHP units and therefore decreases the consumption of fuel. The annual operating costs of DH changes with the integration of waste heat from the industry. The aim of this work is to evaluate the feasibility of integration of waste heat with district heating system.
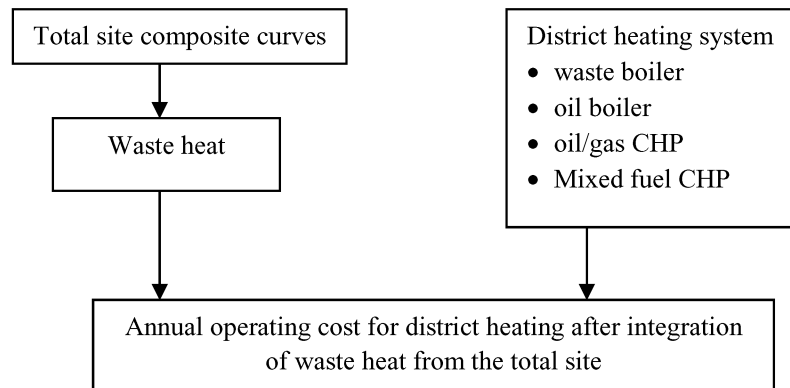

Figure 4: Methodology for techno economic analysis of integration of waste heat from total site with district heating design

4. Results and discussions

4.1 Feasible distance of heat transfer

A simple analysis to determine feasible distance of heat transfer for low grade heat is done in this work. It is assumed that all the low grade heat (62.11 MW) from the total site can be used in a DH system. The selling price for the low grade heat to DH system is 80 $/MWh and the installation cost for the pipe is 1460 $/m (Table 2). The feasible distance for heat transfer based on break even point is 344 km for the given data. However, this analysis is dependent on other factors such as animalization factor, variability of supply and demand in DH, part load performance of DH supply equipments. In the next section, the effect of waste heat integration on an existing DH network is considered.

Table 2: DH network data

Cost installation pipe ($/m)	1460
Selling price of low grade heat to DH ($/MWh)	80

4.2 Integration of waste heat with existing DH network

The optimization is performed for each time period to optimize the consumption of fuel and meet the heat demand for the DH site. Heat supplied by the combination of CHP and boilers is reduced with the integration of waste heat. Revenue is generated from production of electricity and from consumption of waste, while consumption of fuel (oil, and coal) is the cost to the system. The results after optimization for the overall annual cost are shown in Table 3. The revenue from generation of electricity that can be exported to grid is 41.06 M$/y. A small amount of revenue is generated from consumption of waste compared to the cost of the fuel. An overall annual revenue is 41.69 M$/y. Integration of waste heat (62.11 MW) with DH decreases the amount of the thermal load. CHP unit in the DH framework is not run for partial load and the extra thermal load is supplied by the boilers. Therefore, the electricity revenue generated decreases from 41.06 M$/y to 17.23 M$/y. The annual cost of fuel (Fuel-waste) use decreases from -0.63 M$/y to -0.84 M$/y due to the increase in the utilization of the waste heat boiler. The overall annual operating revenue from the district heating system decreases from 41.69 M$ to 18.07 M$. Therefore integration of waste heat with the DH network is not economically viable in the given case study.
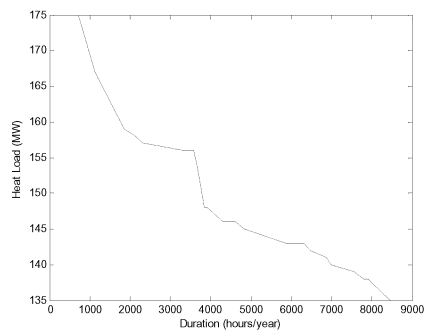

Figure 5: Heat supply after integration of waste heat

Table 3: Effect on annual DH cost by integration of waste heat

	Revenue (Electricity) (M$/y)	Cost (Fuel-waste consumption) (M$/y)	Annual operating Revenue (M$/y)
Before integration	41.06	-0.63	41.69
After integration	17.23	-0.84	18.07

5. Conclusions

The supply of waste heat to the DH network is profitable for a process site until a certain distance from the total site. This is based on the assumption that the heat is supplied to a DH network at a constant rate and does not consider the variability on the side of DH. However, integration of waste heat with an existing DH network decreases the heat production on the supply side. The economic feasibility of integration of waste heat with DH is dependent on the case study. In this work, a case study for DH network is evaluated with respect to economic impacts on the DH network. The case study consists of two boilers and two CHP units with different fuels including waste for the generation of heat. The utilization of waste is economically beneficial to the DH network.

Acknowledgement

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