Energy for Sustainability 2013
Sustainable Cities: Designing for People and the Planet
Coimbra, 8 to 10 September 2013

OPTIMISING HEAT RECOVERY BY INTEGRATING INDUSTRIAL HEAT PUMPS WITH OTHER ENERGY SYSTEMS

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Keywords: Ammonia heat pumps, Smart grid, integrated energy services, Industrial heat pump, Heat recovery, carbon emission,

Abstract *To minimise the carbon footprint and maximise energy output per kg of fuel, we have highlighted how industrial heat pumps in combination with biomass/waste CHP, waste heat recovery, and heating technologies – can optimise total system performance.*

1. INTRODUCTION

Two key terms stand out for future energy providers:

- Integrated services
- Multiple technologies

Integrated services: To achieve the carbon reduction target set by the EU, one of the main objectives is to achieve a much higher level of integrated services[(1)]. If an industrial area produces significant amounts of waste heat while neighboring apartment blocks use boilers to heat homes, a link between these two systems is a logical measure. Such a link ensures that waste heat is upgraded to useful heat and is used beneficially to provide cheap and carbon-neutral heat for residents. Industrial heat pumps play an important role in moving low-grade heat from one customer to another customer in the form of valuable high-grade heat.
Multiple technologies: Today, energy is based on many more than single sources, and all energy suppliers exploit multiple sources of energy. How the energy supplier is able to mix these sources to meet demand determines how successful its business is. Heat pumps play an important role in this mixture of technologies.

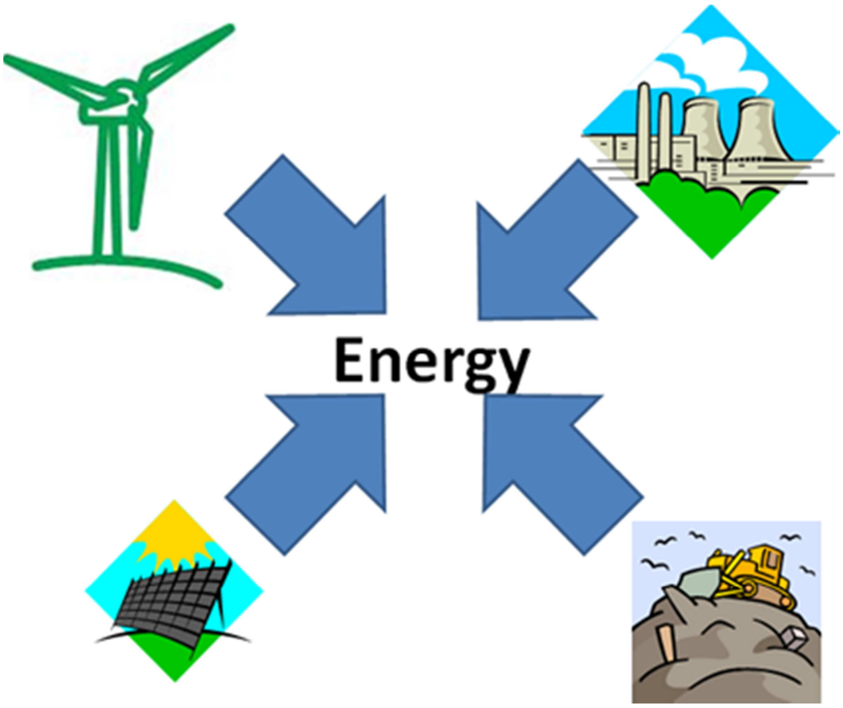

Figure 1: Todays energy suppliers are not basing it on a single source but a combination of several different technologies: wind power, nuclear, gas, coal, oil, pv, waste incineration, biomass, hydro power and heat pumps.

In this presentation we have selected three cases in which we have achieved significant efficiency improvement by integrating industrial heat pump technology into other energy-producing technologies.

2. FLUE GAS COOLING

Heat recovery from any fuel combustion process is an excellent technique for lowering global carbon dioxide emissions. Today most of the World's electricity production is generated without recovering heat from flue gas. Efficient electricity production can achieve efficiencies of 40 to 50 % – but if the heat is recovered, it is possible to obtain energy efficiencies close to 100 %.

When burning fuel with low moisture content such as gas, oil, and coal, most of the heat (over 90 %) can be recovered by direct heat exchange with a hot water circuit. With wet fuels such as biomass and waste, only 80 % of heat recovery from the combustion process is possible by direct heating of water. The final 20 % of heat recovery can be achieved by a wet scrubber system that condenses the flue gases and cools them down to less than 30°C. A wet scrubber system also reduces the toxic emissions from fuel combustion – whether from waste, biomass, gas, or oil. Future restriction on emissions from the EU could make wet scrubber systems a requirement on most mass boiler systems. If a wet scrubber system is installed, the condensate must be cooled – by cooling towers, seawater, absorption heat pumps, or mechanical heat pumps**.** Cooling towers and seawater cooling would waste the heat, but this technique is commonly used where there is only electricity production without heating demand.

A heating system with a combination of CHP and heat pumps provides the opportunity of taking advantage of changes in fuel and electricity prices. If electricity prices rise, operators can utilize the heat pump less and sell more electricity. If electricity prices fall, operators can use the heat pump more and purchase electricity cheaply. If fuel prices rise, they can use the heat pump more, and if fuel price fall, they use the heat pump less. It is most effective to install an algorithm that utilizes the CHP and heat pump most efficiently, in accordance with the cost of fuel and electricity. Industrial heat pumps designed specifically for these markets can be controlled with this level of sophistication.

With biomass shifting from being a local resource to an international commodity – one often transported thousands of kilometers (primarily from North America to Europe)(2) – it is important to optimize the use of biomass to reduce the amount used for each kWh of useful energy.

In February of 2013, a 7200 kW heat pump for a waste incineration plant in Stockholm was installed as the preferred technology. A comparison made by the heat pump center(3) showed that if the electrical heat pump can achieve a COP above 5.0, it is more efficient than an absorption heat pump.

This project is based on cooling flue gas from 50 °C to 25°C by using a single high-efficiency electrical heat pump. The installed systems heat the return heating water from the district heating network from 60°C to 65°C, at a heating COP exceeding 6.50.

3. WASTE HEAT RECOVERY

In many processes, cooling and heating demands are individually covered without a full production layout of heating and cooling needs. This leads to wasteful energy flows in which hot water is cooled by chilled water to achieve the required temperature. We also see many processes with large heating demand at high temperature (e.g., 80°C for pasteurization) and large cooling demand at low temperature (2°C chilled water) – both of which lead to considerable waste heat at medium temperature (35 - 60°C).

Production regimes that generate waste water at 35 to 60°C often use cooling towers to cool this water before sending it to the sewage system: commonly, regulations limit the maximum temperature (around 30°C) of waste water allowed to enter the sewer. The cost of running these cooling towers can be saved by generating useful heat from the waste heat.

The carbon savings and return of investment on waste heat recovery heat pumps can be very attractive – but this all depends on the efficiency of the heat pump. Below is a graph showing the typical COP of a high-efficiency ammonia heat pump, as a function of the temperature lift it needs to perform.

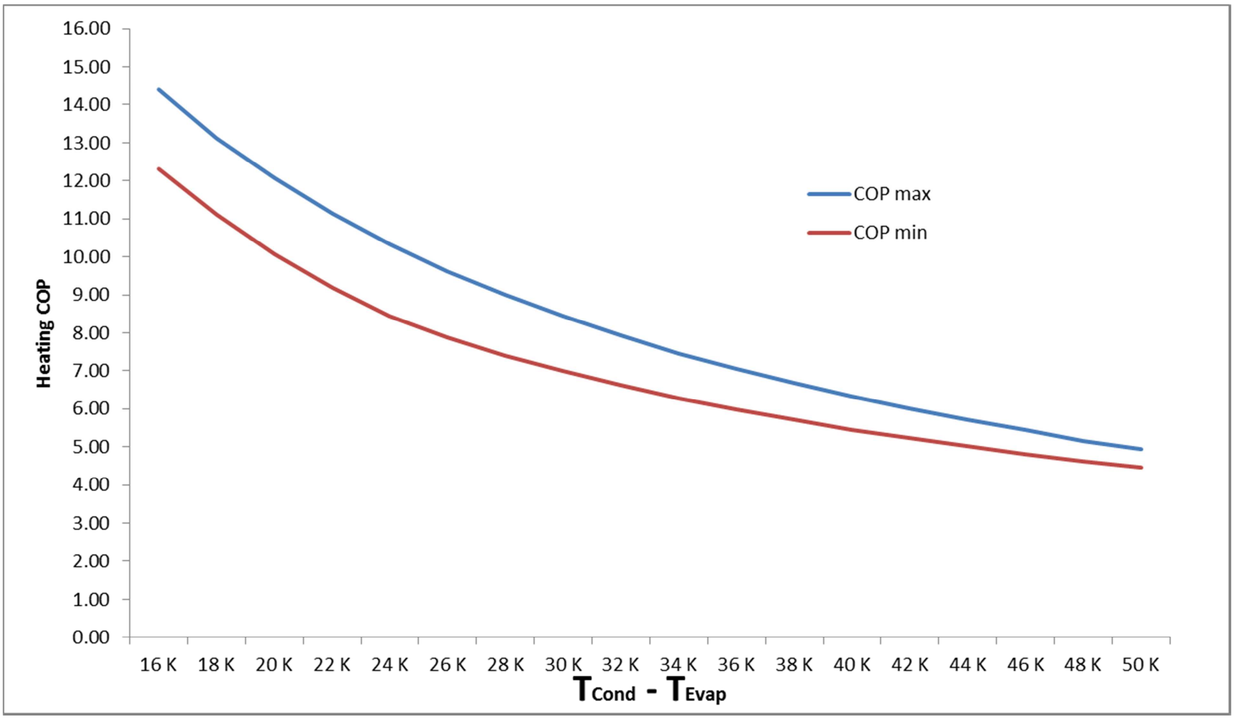

Figure 2: The heating coefficient of performance (COP) as function of the temperature difference between source and output temperature for high-efficiency ammonia heat pumps

Recovering the waste heat and boosting it to provide useful heating results in good payback, reduction in carbon footprint, and lower costs – with heating COP’s from 4 to more than 12.

We often experience that the customer wants to install a heat pump into the existing heating system without the necessary assessment of what temperatures are required. An existing boiler system is likely to be set up to supply water at 95°C to pasteurize milk at 80°C, or to produce steam at 130°C to provide sanitary water at 60°C. Such a configuration is typical because it keeps infrastructure costs down and exerts slight influence on the efficiency of the boiler. These high temperatures make the heat pump uneconomical. If the process heat exchangers can be enlarged in surface area and if the water temperature is lowered, the capital cost increases – but life-cycle costs and carbon savings improve significantly.
In the UK we installed a 924-kW heat pump in a dairy to recover the waste heat from a refrigeration plant at 24°C, and to heat water for pasteurization from 72°C to 82°C[4], with a COP of 4.9. The benefits include achieving payback after 1.5 years and saving more than 1,000 tons of CO_2 per year.

4. SOLAR HEATING

Solar heating is a very efficient way to obtain energy from the sun. Today it is possible to obtain flat solar panels for heating water to 90°C, as well as vacuum tubes to heat water to over 200°C. It is becoming increasingly viable to employ solar heating for urban or district heating networks[5].
To optimize the use of large areas of solar panels, it is important to design hot-water storage tanks and use them in combination with a heat pump. The heat pump can precool the water to the solar panels and boost the hot-water supply temperature to the desired level when there is not sufficient sunshine.

	Heating COP	**DH supply temperature**	**Storage tank temperature**
After 4 hours	6.71	75 °C	38 °C
After 5 hours	6.19	75 °C	35 °C
After 7 hours	5.31	75 °C	29 °C
After 9 hours	4.82	75 °C	23 °C
After 12 hours	3.37	75 °C	14 °C
Average	**5.28**		

Table 1: This table shows the average COP for a heat pump connected to nighttime storage, with an initial temperature of 50 °C.

The heat pump in the table operates with changing evaporation temperature once the storage temperature is achieved. By the next morning, the storage temperature has been cooled to

14°C. By stepped cooling, a higher average COP of 5.28 has been achieved with a payback of less than one year.

Cooling the supply water to the solar panels improves the efficiency of the panels, with more kW per m^2 being generated.

Hot-water storage can also be used during nighttime, during which the heat pump can gradually cool the water during the night and achieve a high average COP. This water storage can be used both as 24-hour storage and as seasonal storage to smooth the differences between summer and winter. For underground seasonal storage, boreholes offer a price-competitive option. Seasonal storage normally costs between €20 and €50 per m^3[(6)]

REFERENCES

- IEA: Technology Roadmap, Energy-efficient Buildings: Heating and Cooling equipment.
- Production and Trading of Biomass for Energy – An overview of the global status, Heinimo J. , Junginger, M.
- IEA Heat Pump Centre, Annex 24, June 1999 – Absorption Machines for Heating and Cooling in Future Energy Systems
- IIR, Add on Heat Pump for Dairy Application, Unsworth R., Vermeer H., Gerritsen J.
- Market for Solar District Heating July 2012 by Jan-Olof Dalenback, Sven Werner.
- SDH 2013: Large-scale Thermal Energy Storage – Status Quo and Perspectives, Thomas Schmidt, Dirk Mangold