Heat recovery from wastewater: Assessing the potential in northern areas

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1 Introduction

Wastewater from the industry and municipalities always contain a certain amount of heat. The temperature of discharged wastewater can be considerably higher and more stable compared to the sourroundigs. Swedish studies have shown that decreasing the temperature of wastewater by one degree by recovering heat can bring 720 GWh of energy savings annually. However, this energy potential is often unused due to the lack of awareness and proper technology. Consequently, heat is discarded to the environment and the embedded energy is wasted. Heat recovery from wastewater could be a considerable source of energy at water utilities. Recovered heat could be utilised for warming the buildings of the water utility or heating water. Processes, such as anaerobic digestion and sludge drying could also benefit from the recovered heat. Furthermore, heat is often being transferred into a district heating system. The use of heat pump technology could also increase the overall efficiency of the heat recovery system by being able to provide cooling energy during the summer season (Tekes, 2013).

2 Objectives of the research

This research is performed as a part of the Water Asset Renewable Energy Solutions Northern Periphery project. The aim of the project is to find and explore hidden, renewable energy potential in the water utilities in the Northern Periphery. In this first stage, we assess the viability of heat recovery from wastewater in northern areas.

3 Heat recovery from wastewater in northern areas

A heat recovery system can be implemented in different stages from its source to the water utilities as we can see from Figure 1. Heat can be recovered immediately after the wastewater is produced (Figure 1a). These applications are often very small-scale and the recovered heat is used for pre-heating domestic hot water. In addition, there are applications in which the heat recovery system has been installed in a sewer (Figure 1b). With this option, the heat transfer area can be relatively large. Conventionally, heat recovery systems are installed at the wastewater treatment plants (Figure 1c) after the wastewater is treated in order to avoid fouling of the heat exchanger. According to Wanner et al. (2004), a restriction with recovering heat before the water treatment process is that the temperature drop can affect the biological water treatment processes, such as nitrification, resulting in a less efficient purification (Tekes, 2013).

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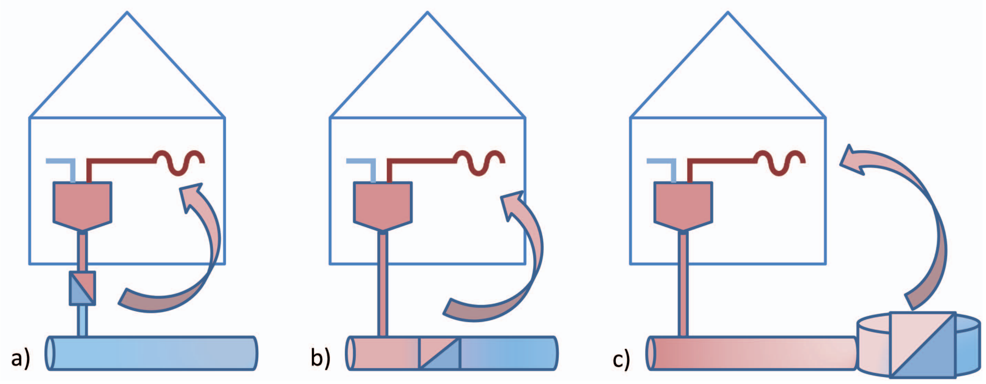

Figure 1 *Options for placing a heat recovery system (based on Eavag, 2013).*

Heat can be recovered from wastewater by using either a heat recovery system or a heat pump. The first system is generally a heat exchanger in which wastewater flows through the exchanger containing another fluid in addition to the wastewater. Heat is being transferred to the other fluid having lower temperature than that of the wastewater. This kind of system is often installed in smaller scale applications, such as in buildings or inside sewer pipes. Larger scale systems often include a heat pump, which is more efficient, even though investment costs of the technology are considerably higher compared to heat recovery systems (Meggers et al., 2010).

In heat pump systems, a working fluid having a temperature lower than the wastewater receives heat from the wastewater. Heat is recovered by an evaporator, which is basically a heat exchanger. The fluid is moved by a compressor, which is also raising the pressure and temperature of the working fluid. Compressed fluid is led to a condenser, where heat is rejected for usage. The rejected heat is not only sensible, but also latent, since a phase change from gas to liquid is often related. After the condenser, the cooled fluid is flowing to an expansion valve, where the pressure and temperature of the working fluid are decreased into a level that heat can be transferred from wastewater to the fluid again. What makes a heat pump often more efficient compared to a heat recovery system is that the energy output is considerably higher compared to the electricity consumption of the compressor. In other words, the coefficient of performance (COP) is higher than two. Furthermore, the heat pump systems often have an advantage of being able to operate the other way around, that is, producing cooling energy (Meggers et al., 2010).

The main factors affecting the energy potential in wastewater is the amount of discharge and the temperature of the wastewater. The amount of wastewater discharge is strongly depended on the amount of citizens. The temperature, however, depends on a number of factors, mostly on the outside and ground temperatures, the length of the sewage pipe and the retention time of wastewater in the sewer. The more the temperature can be allowed to decrease by the utility, the more heating energy can be extracted. However, there are already a few operating wastewater heat recovery processes in northern areas, so this technology is viable also in cold climates (Tekes, 2013).

3.1 Heat recovery plant in Hammarbyverket, Stockholm

Hammarbyverket in Stockholm, Sweden, is the largest wastewater heat recovery plant in the world, receiving a wastewater discharge of 4000 – 18 000 m^3/h. The plant has installed seven heat pumps with the total capacity of 225 MW. These heat pumps are recovering heat from treated wastewater, producing 1235 GWh of heat annually. The produced heat is used to warm up 95 000 residential buildings. In order to maximise production, the plant produces also cooling energy for the district cooling network. In addition, a small, 315 kW turbine is installed in order to produce electricity from the hot side stream (Fortum, 2013).

The temperature of the incoming wastewater from the wastewater treatment plant in Hammarbyverket varies between 7 and 22 °C. After the heat pump system, the temperature of the effluent is 1 – 5 °C. Even though the heat pump system can raise the temperature up to 80 °C, two bio-oil and two electricity boilers are installed in order to increase the temperature up to 120 °C during peak consumption hours and colder periods (Fortum, 2013).

3.2 Heat recovery plant in Lapua

Lapua waterworks in Finland has installed a heat pump system in 2012 with the nominal power capacity of 120 kW. The system recovers heat from wastewater after the treatment process, allowing the temperature to drop to 3 °C. The produced heat is utilised to warm the buildings of the treatment utility. There is no long-term experience of the installed system yet, but it was estimated that the system will be able to save 20 000 euros annually. With an investment of 45 000 euros, this means that the payback period is 2 – 3 years (Tekes, 2013).

3.3 Heat recovery plant in Sandvika, Oslo

In Sandvika, Norway, heat is recovered from wastewater by using a heat exchanger in the main sewer of the community. A heat pump system has been installed in order to get the maximum benefit from the system. Also in this case, the wastewater stream is treated before the heat is recovered with three heat pumps having nominal capacities of 20 MW for heating and 18 MW for cooling energy. The average discharge through the sewer is 3 000 l/s and the temperature of the wastewater is allowed to decrease to 4 °C. The system is estimated to decrease CO_2 equivalent emissions by 6 000 tons annually. The wastewater heat recovery system supplies energy for offices and residential buildings, satisfying more than 50 % of their energy consumption (Tekes, 2013).

4. Conclusions

Heat recovery from wastewater can provide a significant potential for providing heating energy for end-users in northern areas. Even though there is a number of larger scale applications in use, there is still a potential for lower than megawatt scale applications. At the moment, the two main technologies for heat recovery from wastewater include a heat recovery system and heat pumps, where the latter can also provide cooling energy. In most cases, especially in the northern areas, the heat recovery system is installed after the wastewater is treated, in order to avoid fouling and decreased efficiency of biological wastewater treatment processes.

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References

Eavag 2013. Process Engineering. Heat recovery from wastewater. [Online] Available at: http://www.eawag.ch/forschung/eng/schwerpunkte/abwasser/waermerueckgewinnung/index_EN.

European Commission. Directive 2009/28/EC of European Parliament of the Council of 23 April 2009 on the of energy promotion of the use from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

Fortum 2013. Hammarbyverket. Värmeproduktion och kraftvärme. [Online] Available at: http://www.fortum.com/countries/se/om-fortum/energi-och-produktion/varmeproduktion-och-kraftvarme/varmeproduktion/hammarbyverket/pages/default.aspx

Meggers, F and H, Leibundgut (2010) The potential of wastewater heat and exergy: Decentralized high-temperature recovery with a heat pump. Zurich. Elsevier. Tekes (2013) Lämpöenergiaa jätevedestä – katsaus nykytilanteeseen ja mahdollisuuksiin. [Online] Available at: http://www.tekes.fi/fi/gateway/PTARGS_0_201_403_994_2095_43/http%3B/tekes-ali2%3B7087/publishedcontent/publish/programmes/vesi/documents/130210_katsaus_lampoenergiaa_jatevedesta.pdf

Wanner,O; Vassileios, P; Clavadetscher, P; Hansruedi, S (2004) Effect of heat recovery from raw wastewater on nitrification and nitrogen removal in activated sludge plants. Elsevier. Zurich.