Factsheet – Low grade heat recovery from wastewater

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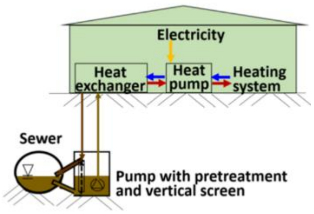
DATE: 11/01/2021

VERSION: V2

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and

Low grade heat recovery from wastewater



Unique selling points:

- ✓ Heat recovery or cold air generation
- ✓ Energy-efficient alternative to boilers or air conditioners

Description of the technology

Domestic wastewater usually contains heat, especially if it results from processes operated at warm temperatures such as showering, clothes washing, dishwashing, etc. This heat can be recovered either within houses in small scale applications, from the sewer in small scale (5 kW – 150 kW) to medium scale applications (150 kW – 700 kW) or at wastewater treatment plants in large scale applications. The further away from the heat source, the more energy will be lost into the environment.

Here, the focus is put on the medium scale application. Wastewater entering the sewer system has usually a temperature between 10 °C and 20 °C or even more depending on its source and on the outdoor temperature. The available heat varies over time, due to temperature and flow variations. The heat is recovered via a heat exchanger located in or near the sewer (Fig. 1). The heat exchangers currently used in this case transfer the heat from the wastewater to a closed heat exchange loop. The heat medium in the loop is normally water. Usually plate heat exchangers or shell-and-tube heat exchangers are applied. The heat exchanger is coupled to a heat pump. The heat pump abstracts the thermal energy at an elevated temperature enabling its reuse such as for heating purposes of a nearby building.

In summer, the heat pump can also be operated reversely, in order to cool a building and thus, (partly) substitute a conventional air conditioner. The heat collected from the environment by the heat pump is in this case transferred to the wastewater.
In comparison to an air conditioner or a boiler, a heat pump is much more energy efficient. Nevertheless, to enable space heating in a building, the heating system in the building needs to be adapted to low-temperature heating systems.

In NextGen, the heat is recovered in a sewer mining unit that includes a membrane bioreactor (Fig. 2). The treated wastewater effluent from the **membrane bioreactor (MBR)** is used for heat recovery. The effluent has a temperature between 15 °C and 20 °C. The contained heat is recovered from the effluent via a heat exchanger located in the wastewater effluent tank. The heat exchanger transfers the heat from the wastewater to a circulating water. The heat exchanger is coupled to a heat pump (Fig. 3). The heat pump increases the heat for pre-heating of the incoming mixture to the **rapid composting bioreactor** unit.

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Flow schemes of the technology:

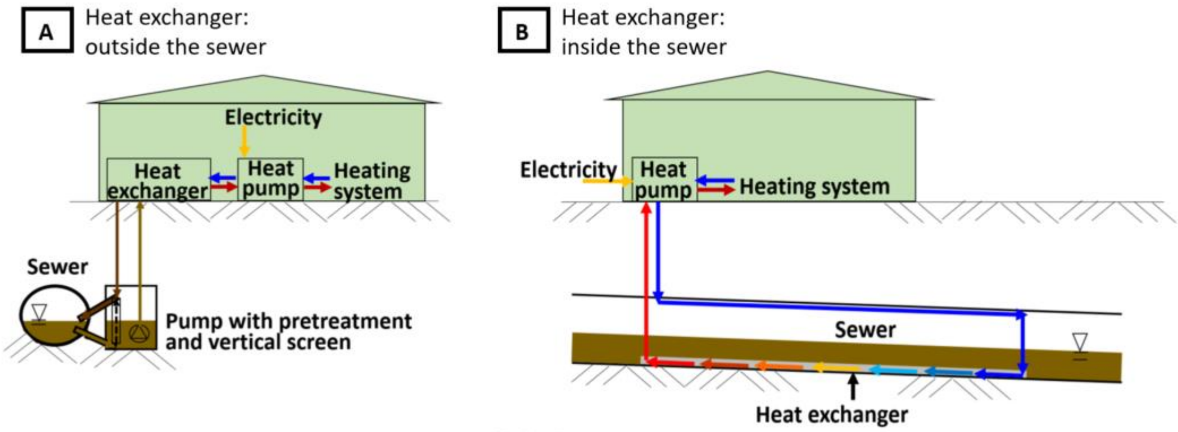

Fig. 1 Thermal energy recovery: a) outside the sewer and b) inside the sewer

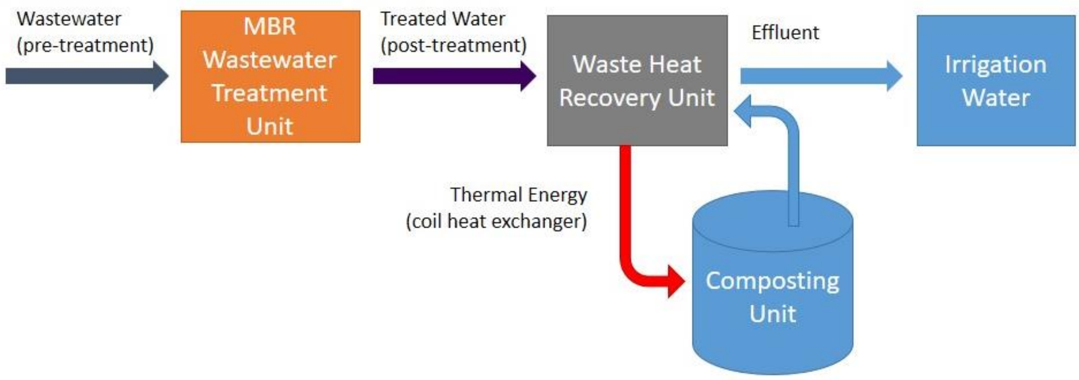

Fig. 2 NextGen project: sewer mining unit with the thermal energy recovery from the effluent of the membrane bioreactor (MBR)

Picture of the technology

Fig. 3 Example for a heat pump as a part of a low grade recovery system

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Synergetic effects and motivation for the implementation of the technology

- ✓ **Energy efficient heating and cooling dependent on the season**

The heat pump uses available excess heat as an energy source and thus, its energy efficiency is much higher than a conventional air conditioner or a boiler. Depending on the conditions such as temperatures etc., the heat recovery system can replace cooling and heating units operated with fossil fuels.

- ✓ **Thermal energy storage**

Recovery of the heat and the demand for heat will not always occur in the same time. Often it is required to store the heat. For smaller systems, water tanks or phase transition heat storage systems can be used. For larger systems, ATES systems can provide an adequate solution. The latter also allow longer-term seasonal storage.

Requirements of the technology

The efficiency of the heat recovery in a sewer relies on different parameters such as the flow rate and temperature in the sewer, the temperature difference of the wastewater upstream and downstream of the heat exchanger, the geometry of the pipe and of the heat exchanger, the viscosity of the wastewater, the velocity of the fluids in the heat exchanger, the heat transfer resistance caused by biofilm formation, the heat exchange coefficient and the heat transfer surface area. According to Brunk et al. 2013, the flow rate in the sewer should be at least 15 L/s with a sewer diameter of at least 800 mm for such a system. However, Brandenburger Liner (2021) indicate minimum diameters of 300 mm and flow rates of at least 8 L/s. In general, the necessary flow rate and diameter depend highly on the certain technology which will be applied. For example, in Bologna flow rates between 200 and 400 L/s were used (Cipolla and Maglionico 2014) and in Brno (Czech Republic), the flow rates ranged between 130 L/s and 470 L/s (Cecconet et al. 2019).

When heat recovery is applied, the temperature of the wastewater should not be reduced below 10 °C. If the temperature in the wastewater decreases below 10 °C for example during winter times, the biological purification processes might be affected negatively in the subsequent wastewater treatment plant (Wanner et al. 2005) and increasing its energy demand. Thus, before planning such a heat recovery unit, it should be carefully investigated which temperature will result in the influent to the corresponding wastewater treatment plant. Hereby, mixing effects with warmer flow streams might neglect the effect from the heat recovery in a certain sewer. Elías-Maxil et al. (2017) and Bailey et al. (2020) have developed modelling tools to predict heat availability and temperatures in sewer networks.

Parameter	Units	Min	Max	Reference
Sewer pipe diameter: **Circular profile** **Oval profile**	mm	300 250/375	1300 1300/1950	Brandenburger Liner 2021
Flow rate	L/s	8	470	Brandenburger Liner 2021; Cecconet et al. 2019
Length of sewer with a straight line	m	20	200	Brunk et al. 2013; Brandenburger Liner 2021

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Temperature of wastewater before heat extraction	°C	10	-	Buri and Kobel 2005
Temperature after heat extraction in the influent to a WWTP	°C	10	-	Buri and Kobel 2005

Key performance indicators

The heat recovery system consists of the heat exchanger in the sewer and the heat pump. Thus, there are at least two key performance indictors to be considered.

The performance of the heat exchanger is usually indicated as heat transfer efficiency or as heat transfer coefficient. It should be noted that the wastewater may lead to the formation of a biofilm on the heat exchanger. That can diminish its heat transfer efficiency. According to Brunk et al. 2013, the biofilm can function as an insulating layer between the wastewater and the heat exchanger depending on its thickness. This can lead to a decrease in the temperature difference of up to 5 K. Besides biofilm formation, also scaling and corrosion processes can contribute to a decrease in the heat transfer efficiency of heat exchangers. In practise to overcome the fouling effect, either the heat exchangers have an oversized surface or anti-fouling surfaces are used for the heat exchangers.

For the heat pump, the coefficient of performance (COP) is defined as the ratio of the discharged thermal energy and the sum of the thermal and electrical energy charged to the heat pump. Here, the temperature difference of the two sources influences the COP. The higher the temperature difference is, the higher the COP is. However, if the performance of the entire heating or cooling system including the heat pump and other pumps for circulating fluids over an entire season shall be assessed, the seasonal performance factor must be considered.

Parameter	Units	Min	Max	References
Heat exchanger efficiency (plate heat exchanger)	%	69	91	Torres Tamayo et al. 2016
Heat transfer coefficient (plate heat exchanger)	$W/(m^2 K)$	2500	8000	Torres Tamayo et al. 2016
Coefficient of Performance (COP_H) for heating	-	3	5	Cipolla and Maglionico 2014, Soltani et al. 2015
Seasonal performance factor (SPF_H) for heating	-	4	5	Buri and Kobel 2005
Coefficient of Performance (COP_C) for cooling	-	3.9		Cecconet et al. 2019
Seasonal performance factor (SPF_C) for cooling	-	4	6	Banks 2012

Links to related topics and similar reference projects

Processes/ technologies	Reference
Low grade heat recovery in sewers	**Case study Athens**
ATES	**Case study "Westland"**

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Outlook

Case study specific information will be provided, when the results of the other work packages are available:

- **Lessons learned from the case study**
- **Outcome of the assessments**
- **Legal and regulatory information concerning the whole value chain concerning the technology**

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- **Business opportunities**

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