Waste heat recovery from sewage water

Sewage water can be used to recover waste heat for heating or for cooling buildings using different types of heat pumps and is thus viewed as a renewable heat source. The use of waste water has high energy potential mostly due to the fact that the temperature of the sewage water is relatively high, usually above 10 °C, which makes it a good source of heating.

The technological solutions for recovering heat from sewage water are relatively simple. Numerous companies offer technical solutions. Barriers for the use of these systems are technical and economic. Investigations on the technical feasibility for installing such systems as well as investigating the financial potential compared to conventional heating solutions need to be performed.

The potential of sewage water covers the base loads of the buildings' heating demand and backup systems that are needed to cover peak loads. However the use of sewage water has high technical potential since sewage water can be utilized with district heating grids and may thus be used to improve the overall energy efficiency of heating and cooling systems for the city. Since this type of heat recovery systems can also be combined with heat pumps or similar heat recovery systems utilizing less energy compared to conventional heating sources the primary energy consumption and CO_2 emissions can be reduced.

Case studies

Recovery of heat from sewage water has been implemented in Gothenburg and in Cologne. The following amount of energy has been recovered in Cologne since 2014

Energy [MWh]Energy recovered from sewage waterSource: Deliverable 4.3 *There is still no data available from 2017CO1 WahnCO1 Mülheim20142015201620170100200300400Highcharts.com

Best available technology

Waste heat in sewage water is a resource which can be recovered instead of flushed away. Photo: drainrat via Flickr (link)(CC BY 2.0).

There are different technical solutions for heat recovery from sewage water. Different types of heat exchangers are used in combination with various heat pump types. The heat exchanger system is an important factor to be able to utilize sewage water as a heating source and in its turn affects how efficient the heat pump will be.

The two main technical solutions for heat recovery from sewage water, sewer-external heat exchanger solutions and in-sewer heat exchanger solutions, both have their advantages and disadvantages. Sewer-external heat exchanger solutions are limited by the sewage water flow, the sewage water temperature and the area available for the installation of the equipment. However these systems have high technical flexibility and the installation is easy and accessible for maintenance and service. In-sewer heat exchanger solutions are mostly limited by the state of the existing sewer system, the length of straight runs and slopes as well as the sewage water flow. The advantages for the system is the lower auxiliary power consumption needed compared to the sewer-external systems. Both systems are suited for various applications such as residential developments, office buildings, district heating projects, swimming pools, industries, schools and more. The decision for which system to use should be performed on a case by case basis.

Sewer-external heat exchanger systems

The principal of the sewer-external heat exchanger solutions are that wastewater is removed from the sewer into a so called wet well from where the sewage water can be used in various ways. The actual heat exchange process does not take place inside the sewer but outside of it, either by using the sewage water, usually treated, in an intermediate circuit to the heat pump or it is pumped directly to the evaporator of the heat pump.

The advantages of this system are the high technical flexibility since standardized products can be used due to the fact that things such as the sewer pipe design, cross-section and slope does not affect or limit the design and type of heat exchanger. The installation is easy and accessible for maintenance and service. This system is however limited by the sewage water flow, the sewage water temperature and the area available for the installation of the equipment needed for the treatment and pumping of the sewage water. Fouling is another factor that presents a challenge for this type of system however this can be prevented by treating the sewage water before it is used in the heat exchanger or the heat pump.

Two sewer-external heat exchanger types are further described and presented in the subsections below.

Sewer-external heat exchanger type 1
Huber Technology’s solution *ThermWin* for extracting heat from the sewer is such that from the sewer pipe there is an outlet that allows part of the sewage water to flow into a so called wet well, a space where the sewage water is gathered. In this space a cleaning device is installed to pre-clean the sewage water before it is either pumped further into a heat pump where the heat exchange and compression will happen, or the treated sewage water is pumped to an external heat exchanger and is then further processed in a heat pump. After the heat exchange the wastewater is returned to the sewer via a pipe connected to the sewer line. Schematic of the system is shown in Figure 4

Figure 4. *ThermWin* system by Huber Technology.

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Factors that mostly determine the available heat potential of the system is the dry weather flow that must be sufficient enough and the temperature of the sewage water. The dry weather flow is defined as the average daily sewage flow entering a sewage treatment plant or sewer measured following 7 days without rain and during which on the preceding 7 days, rainfall did not exceed 25 mm on any day. The requirements for optimum operation of this system are that the dry weather flow of the sewage water should reach at least 10 l/sec and the average temperature in winter should not fall below approximately 10 °C. Another factor to take into consideration for these types of systems are the distance between the sewer and the building to be heated that should be as short as possible.

Advantages of such a system are that with this design clogging can be prevented, the system is compact and different types of heat exchangers can be used minimizing the cost of the system by not needing specially design heat exchanger. Other advantages are that the installation is easy and the system is accessible for maintenance and service. This technical solution is suitable for heating of nearby buildings, typically bigger buildings, such as sport facilities, swimming pools, schools, kindergartens, residential buildings, office buildings or industries.

Huber Technology has developed a checklist for the *ThermWin* system to help determine and estimate whether it is technically reasonable and feasible to use this system for a specific project.

Sewer-external heat exchanger type 2

Another technological solution using sewer-external heat exchanger systems to recover energy from sewage water is to have the pre-cleaned sewage water go via an intermediate circuit to the evaporator of the heat pump. An example from this type of solution is the SHARC system from International water systems. The SHARC system processes raw sewage water provided from a wet well. The treated sewage water is then pumped through an external heat exchanger that recovers heat from the sewage water that is then further processed in a heat pump. Afterward treated wastewater is returned to the sewer.

Similar to the Huber Technology system one of the advantages of the SHARC system is that the installation is easy and accessible for maintenance and service. International water systems states that the system has a self-contained clog-proof filtering system and reduces odour issues and fouling. However the available heat potential of the system is dependent on the temperature and the flow of the sewage water. The system is suitable to be used for heating of nearby buildings of, sport facilities, swimming pools, schools, kindergartens, residential buildings, office buildings, hospitals or industries.

In-sewer heat exchanger systems

In an in-sewer technological solution the heat exchange process takes place inside the sewer. The heat exchanger is installed either on the bottom of the sewer pipe which then transfers heat to an intermediate circuit to a heat pump or the sewer pipes can be encompassed by loops containing a heat transfer medium that transfer heat to a heat pump.

The advantages of this system is that lower auxiliary power consumption is needed compared to the sewer-external systems. The disadvantages of this system are the higher installation costs as well as the fact that the system is highly dependent on the sewer design and the state of the existing sewer. Similar to the sewer-external systems additional limitations are the sewage water flow and temperature. This system can also present problems with fouling on the heat exchanger surface. To prevent problems with fouling that may occur solutions that can be implemented are to treat the sewage water before it flows in the sewer by different filtration techniques, special materials can be used and structures of the heat exchanger surfaces in combination with optimizing the flow rates. Then there is also cleaning of the heat exchangers after certain periods of operation or it is also possible to enlarge the heat exchanger surface.

Three in-sewer heat exchanger types are further described and presented in the subsections below.

In-sewer heat exchanger type 1

TubeWin by Huber Technology uses heat exchanger elements installed directly in the sewer pipe bottom. The heat exchanger elements are made of stainless steel and connected in parallel or in a serial way via an intermediate circuit to a heat pump. This gives the system flexibility to be able to be installed in different types of sewer shapes. Schematic of the system is shown in Figure 5

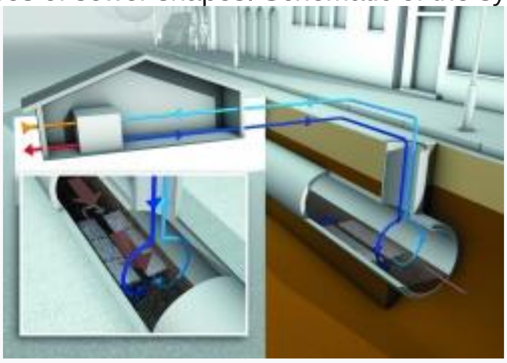

Figure 5. *TubeWin* by Huber Technology.

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One of the advantages of this system is that no extra space is needed for the heat exchanger since it is directly installed in the sewer pipe. Due to the design of the heat exchanger elements the system can be used in various sewer cross-sections, as small as 1000 mm. The advantages of this system are its robust design, low pressure losses and it reduces problems of fouling and clogging in the heat pump system. Similar to the sewer-external systems this solution's limitations are the sewage water flow and temperature. Other limitations with the system are problems with fouling, by waste build-up on the surface of the heat transfer panels that reduces the amount of available heat.

The system's application are similar to the *ThermWin* system, as it is suitable for heating of nearby buildings, such as sport facilities, swimming pools, schools, kindergartens, residential buildings, office buildings or industries.

In-sewer heat exchanger type 2

Rabtherm Energy Systems have developed sewer elements with an integrated heat exchanger. There are a variety of series and technical solutions of these systems, that can be used both in existing sewers or that can be integrated in new sewers. The heat extraction system comes in four alternatives:

- Integrated heat exchangers in the sewer pipe (new sewers)
- Built in heat exchangers in existing sewers
- Prefabricated slide-in modules
- Pressure pipe heat exchanger

Focus will be on *Rabtherm Series I* which can be seen in Figure 6 and need to be integrated in new sewers.

Figure 6. Sewer element *Rabtherm series I*.

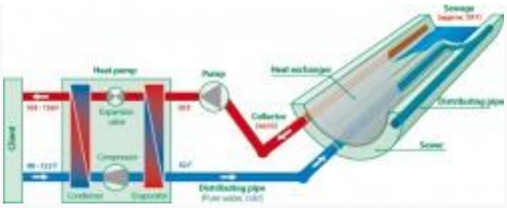

Figure 7. Principal schematics of the *Rabtherm series I*.

Figure 7 shows a representation of the design and principal of how the system works. The heat exchange happens through stainless steel heat exchangers in the bottom of the sewer which are connected directly to a heat pump with two pipes (distributing to, and collecting from the heat exchanger elements). A third pipe brings the return from the heat pump to the bottom of the sewer pipe.

The criterion for this system is that the sewer diameter should be a minimum of 400 800 mm with an average water flow of minimum 9 l/s. The distance between the sewer pipe to the consumer should be maximum 200-300 m, for economic reasons.

The advantages of this system are that the sewage water does not need to be treated as it is not used directly in the heat pump thus reducing problems of fouling and clogging in the heat pump system. Rabtherm Energy System has also developed a solution for reducing biofouling on the heat exchanger element in the sewer pipe. With this patented antifouling system, the performance of the heat exchangers is increased by 30-40%.

Limitations of the system lie in the installation locations since the system needs to be integrated in new sewers. This system suits consumers with a heating demand from 50-4000 kW for the heating of nearby buildings, such as sport facilities, swimming pools, schools, public buildings, residential buildings, office buildings or industries.

In-sewer heat exchanger type 3

PKS-Thermpipe by Frank GmbH is designed for the heating of nearby buildings. The sewer pipe is surrounded by loops that transfer heat to a heat pump or to a boiler. For this system the *PKS Thermpipe* will be installed instead of a standard sewage pipe.

The criteria for this system are that the dry weather water flow should be greater than 15 l/s and the distance between the sewer pipe to the consumer should be maximum 100-500m.

The advantages with this system are that it has great durability and that it draws heat from the sewage water as well as the surrounding soil. Other advantages are that sewage water does not need to be treated as it is not used directly in the heat pump thus reducing problems of fouling and clogging in the heat pump system. Limitations of the system lie in the installation locations since the system needs be installed in new installations and replaces the standard sewer pipe.

Best practice

The energy company in Gothenburg, Gothenburg Energy, utilizes sewage water for the production of heat. The mean temperature of the sewage water in Gothenburg is approximately 11 °C but varies between 8 - 14 °C. It is passed through four heat pumps in a cascading technique which increases the temperature of the heating medium in steps in an efficient way. The sewage water temperature out from the heat pumps is not reduced below 3 °C.

The output temperature from the last heat pump which is delivered to the district heating system is kept to around 80 °C. However the system is connected to two hot water boilers that run with pellets, which can be used when needed. That is if the temperature out from the last heat pump is around 65 °C.

The temperature returning from the district heating grid is approximately 40 - 55 °C. The plant delivers heat through the hot water boilers to the district heating grid. Momentary data provided by Gothenburg Energy show that the plant can produce 150 MW of heat with a COP of 3.4 without the use of hot water boilers for increasing the temperature to 80 °C.

The demonstrator in Cologne is described in the demonstrator article.

Comparison between the technologies in Gothenburg and Cologne

The sewer heat exchanger used in the Celsius demonstration in Porz-Wahn, Cologne is a good choice since it has high flexibility to be able to be installed in different types of sewer shapes, thus also used for the demonstration in Mülheim where the sewer pipe's design differed. Another advantage of the use of this system is that no extra space is needed for the heat exchanger since it is directly installed in the sewer pipe. The advantages of the system were its robust design and low pressure losses. The system chosen also reduces problems of fouling and clogging in the heat pump system. However since the metal plates are installed directly in the sewer problems with fouling may occur, where waste build-up on the surface of the heat transfer panels will reduce the amount of available heat.

In the Gothenburg system the heat pump system used to heat the water to provide heating, is supplemented with two hot water boilers which run with pellets and which are only used during some periods when needed. Compared to the demonstration in Porz-Wahn the system by Gothenburg Energy uses multiple heat pumps to increase the temperature of the water in a cascade system. In Porz-Wahn one heat pump is used and is supplemented with a gas boiler which is used continuously.

Gas is not used in the same manner in Gothenburg as in Cologne thus only heat pumps are used to increase the water temperature. When the hot water boilers that are operated with pellets are used the temperature out of the heat pump system is lowered, in that way higher values of COP can be achieved.

Strategies to improve performance

1. **Choice of sewer heat exchanger system**
   The heat exchanger used to extract heat from the sewer is an important system affecting how efficient the heat pump producing heat will be. There are different technical solutions for heat recovery from sewage water. For new installations integrated heat exchangers in the sewer pipes should be assessed to determine if it would be a better solution than installing heat exchanger systems that are not integrated in the sewer pipes.
   However heat exchanger systems that are not integrated in the sewer pipes have high flexibility and are easily maintained and serviced thus making these systems a better solution for extracting heat from sewage water. Evaluations need to be performed to decide which type is best suited for a sought installation both technically but also economically. The sewer heat exchanger system to be used should also preferably not use the sewage water directly in the heat pump to prevent issues with fouling and clogging in the heat pump system. An external heat exchanger should be used or a cleaning system for the sewage water that will be easy to maintain and service.
2. **Evaluate possible fouling issues**
   For the in-sewer heat exchanger system used, metal plates are installed directly in the sewer. Problems with fouling may occur where waste build-up on the surface of the heat transfer panels will reduce the amount of available heat. To prevent such problems it is important to evaluated and assess the fouling possibilities and implications as well determine possible solutions to reduce the fouling.

3. **Optimize the heat pump operation with supplementary heating**
   Improvements possibilities can be found by evaluating the most optimum operation of the heat pump and the chosen solution for supplementary heating. When supplementary heating is needed the output temperature from the heat pump should be lowered. In such way the COP is increased compared to when the heat pump is producing higher output temperatures. Preferably the heat pump and the supplementary heating system should not be operating continuously at the same times, but the supplementary heating should be used only for the times the heat pump is not able to cover the total heating demand of

the building. An assessment should be performed if using a heat pump to provide higher water temperatures and using supplementary heating only during some periods is a more efficient operation, than running the heat pump at lower temperatures and using supplementary heating continuously. Barriers for the type of operation are economic reasons thus investigations on the financial potential need to be performed but should also be weighted to environmental benefits.

4. **Analyse the heating system for the buildings** The three sites in Cologne are designed to provide a quite high output temperature (80°C). It could be beneficial to make improvements in the building's heating systems to see if there is a possibility to lower the temperature demand and thus obtain a better systems performance.