Heat4Cool – Task 8.3 Education and training.

TRAINING MATERIAL

In the framework of T8.3 of the Heat4Cool project, we are presenting you the training material dedicated to each of the four demo sites involved in the project, and the different technologies tested and installed in these facilities.

This training material aims to present to external stakeholders the functioning of the Heat4Cool technologies installed in each demo, and present the systems developed within the project; thus, to allow a better comprehension, increase the interest of the audience and promote the use of the project solutions in the market.

The training material is divided into **four dossiers,** each one dedicated to one demo site.

The Project has received funding from the European Union's Horizon 2020 programme for energy efficiency and innovation action under agreement No. 723925.

Demo site in Budapest (Hungary)

Demo manager: Thermowatt

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1 HEAT4COOL PROJECT INTRODUCTION AND OBJECTIVES

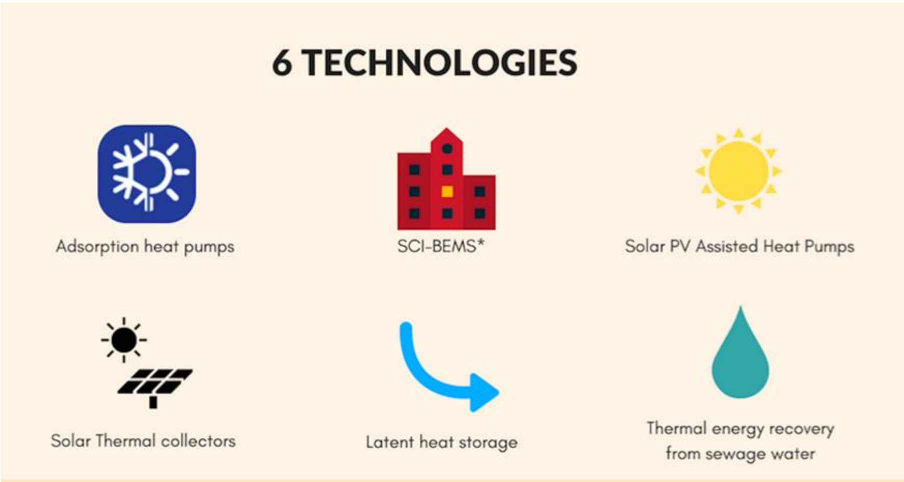
1.1. Introduction

The Heat4Cool project is an EU funded project, started in October 2016 and will run for four years.

The project proposes innovative, efficient and cost-effective heating and cooling solutions to optimize the integration of six technologies:

- Adsorption heat pump,
- PCM storage batteries,
- SCI-BEMS, Solar PV,
- Solar thermal,
- Heat recovery from sewage water

at building and district level, to meet net-zero energy standards.



The project will showcase four different retrofitting solutions, three of them will be focusing on residential buildings where the new innovative systems will be monitored and controlled through the SCI-BEMS (self-correcting intelligent building energy management system).

1.2 Testing technologies

The technologies based on solar energy and heat pumps developed within the Heat4Cool project are being implemented in Tecnalia's Kubik® facility, located in Bilbao (Spain).

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In the facility, Tecnalia tested the thermal storage system coupled with a reversible heat pump and the solar driven adsorption cooling system.

The main aim of these tests is to carry out a proof of concept for two complete systems in order to assess the thermal performance of Heat4Cool solutions under realistic boundary conditions. These two systems are already connected to the centralized HVAC system to test the effective integration of the heating and cooling technologies.

The thermal storage system coupled by a reversible heat pump is the concept solution developed by Sunamp. A total of 7 PCM (Phase change material) heat storages connected to an air to water electric heat pump have been installed. This is the first version of the system that will later evolve to a DC driven heat pump connected to a PV panel field, a solution that will be implemented in the pilot buildings of Sofia and Chorzow. The system to be tested in Kubik will allow improving the interaction between the heat pump and the heat storages while the contribution of the solar field will be post-processed.

The solar-driven adsorption cooling system has Fahrenheit's Zeolite prototype chiller as the main innovative component. Combined together with a solar thermal field composed of flat plate collectors, the heat pump will produce cold water that will be stored into an 800L tank connected to the cooling circuit. As a result of the adsorption process, waste heat will be produced at medium temperature (35-40 °C), which will be used for preheating of domestic hot water or dissipated to the atmosphere by means of a dry cooler unit.

Preliminary tests have been performed for both sets and performance data of the components are being collected to evaluate the contribution and benefits of implementing both concepts.

1.3 Project Outcomes

The integrated solutions developed and tested in Heat4Cool project will provide:

- **Space heating, cooling and domestic hot water** in one case by integrating the Adsorption heat pump to the natural gas boilers, and in the other case by coupling the DC heat pump powered by photovoltaic panels and PCM storage.
- **Renewable energy solutions**
- **Smart control system** which the "brain" of the heating and cooling energy system and will constantly monitor the environment conditions and the performances in order to identify the optimal option in terms of comfort and energy efficiency.

Heat4cool project aims to achieve:

- a **reduction of 30% in energy consumption** in a technically, socially, and financially feasible manner,
- demonstrate a **return on investment** lower than ten years,

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- and provide **best practices examples** for the construction sector.

1.4 Demo sites introduction

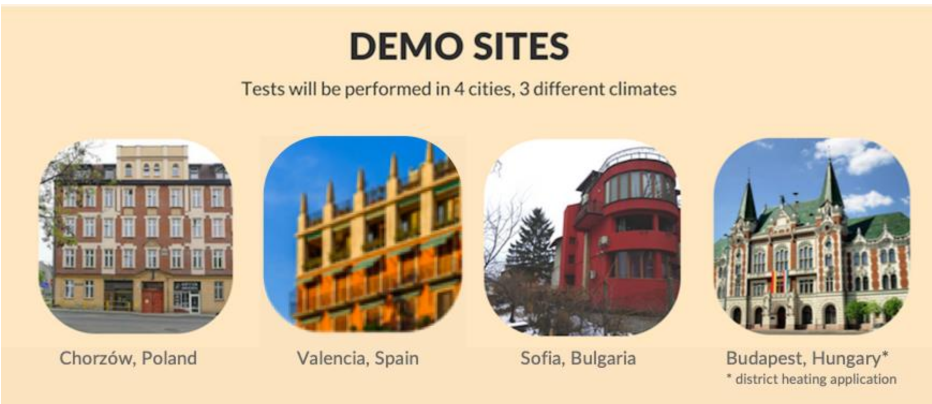
The Heat4Cool technologies has been installed and tested in four demo sites located in three different climate areas in Europe.

1. **Chorzow, Poland**
    - The building is a multi-story house with three commercial premises and one residential apartment on the ground floor and 11 apartments on the other floors (12 residential apartments in total) with a total floors area of 998 m^2. Only 11 apartments have been retrofitted within the project.

2. **Valencia, Spain**
    - Apartment housing composed by composed by 12 flats, 610m^2 of total floor area.

3. **Sofia, Bulgaria**
    - Residential building, 3 apartments, total floor area of 564m^2.

4. **Budapest, Hungary**
    - District H&C system supply 3 different buildings: two public buildings (a recently retrofitted over 100-year-old and a ~2-decade-old building) and one newly constructed mixed-purpose building (commercial and cultural institution).



1.5 Consortium

The Heat4Cool project is composed by 13 partners from 7 associated European countries, more into details:

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- 3 research organisations
- 9 SMEs
- 1 non- profit organisation

Project coordinator, Politecnico di Milano – Dr. Marcello Aprile (marcello.aprile@polimi.it)

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2 TECHNOLOGY INTRODUCTION

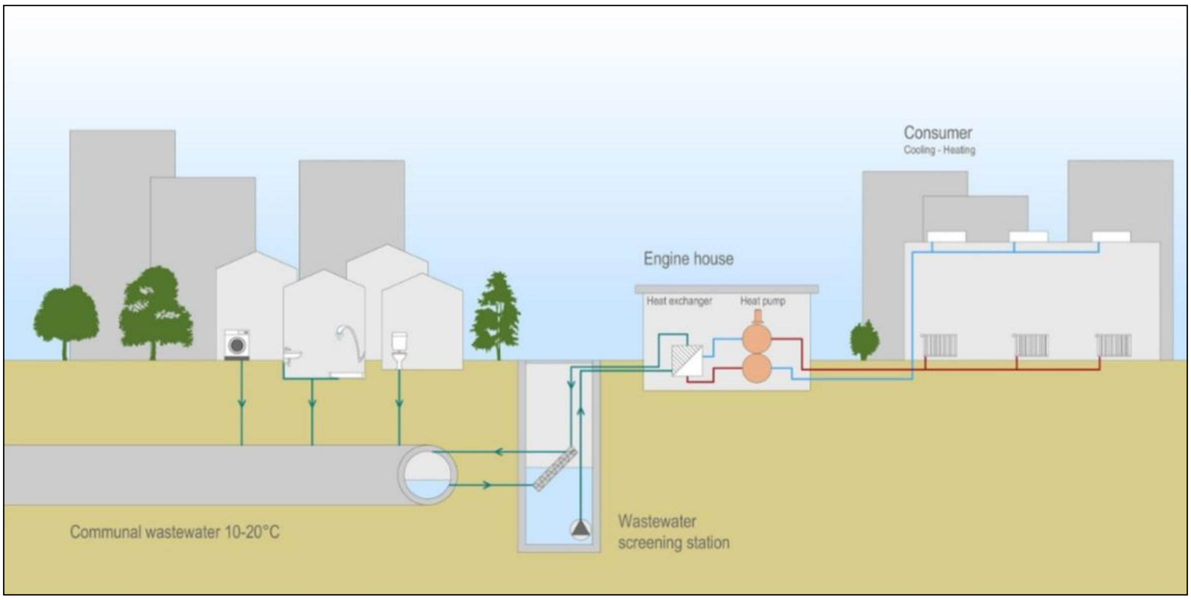

Figure 1. Scheme of the Thermowatt technology

Thermowatt has developed a unique solution to recover thermal energy from sewage to heat and cool buildings.
Sewage is an overlooked energy source. However, under continental climate sewage's almost constant 17°C temperature all year round makes it an ideal energy source for a heat pump. During winter it is much more economic for a heat pump to extract heat energy from the 17°C warm sewage than from the 0°C cold outside air. Likewise, during summer it is more efficient to extract cold energy from the 17°C mild sewage than from the 30°C hot outside air. In addition, sewage flows in city centers where demand for heating and cooling is high.
Two obstacles remain:
1. sewage is too polluted for a heat pump to work with and
2. the limited space in city centers for traditional sewage cleaning technologies.

Having these obstacles solved a solution was created. The sewage gets directed from the city sewer lines through specifically designed filtration equipment to unique heat exchangers. The heat energy recovered by the unique exchangers can then be safely passed onto heat pumps that provide heating and cooling to the user. And since the source is collected from public sewers (with notable construction effort), fully utilizing the size of a given flow and supply for multiple buildings through the same system – much like a district system – makes perfect sense.
This entire process is operated by Thermowatt control system. The project can be installed underground and therefore can be used even in densely populated city centers.

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As part of the development of the wastewater heat utilising heating and cooling technology taking over part operation of the base system, new prototype experimental Heat Exchangers, Screening unit and accompanying equipment/piping were implemented at the Demo 4.

2.1 Blueprint:

As part of the R&D task in the Heat4Cool project, new- innovative heat exchangers were designed and a developed screening unit (filtration) was introduced.
Out of the 5 new designs presented as the outcome of the R&D tasks, considering circumstances of available space and budget 2 HEX designs were chosen for the inclusion of the demo site implementation.

Here are the designs of the HEX units as well as the Screening unit, from which experimental models were manufactured and consequently implemented in the underground engine house connecting the supplied buildings of the Budapest Demo site.

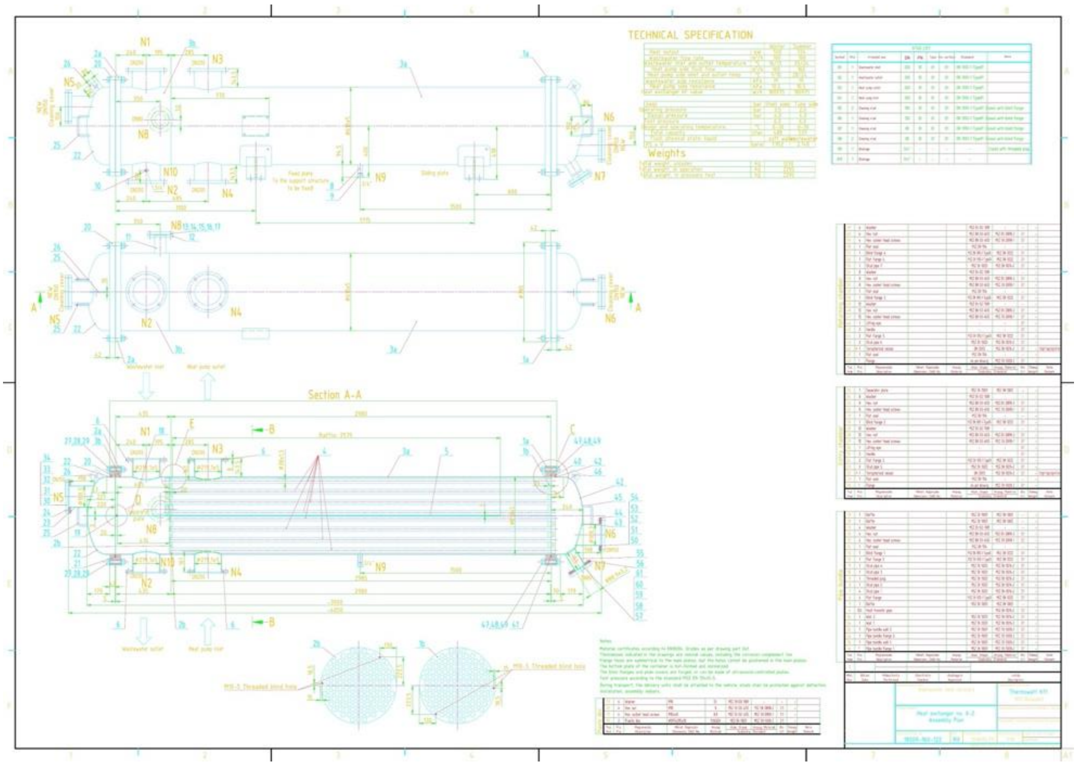

Figure 2. Blueprint of experimental Heat exchanger - A2 type

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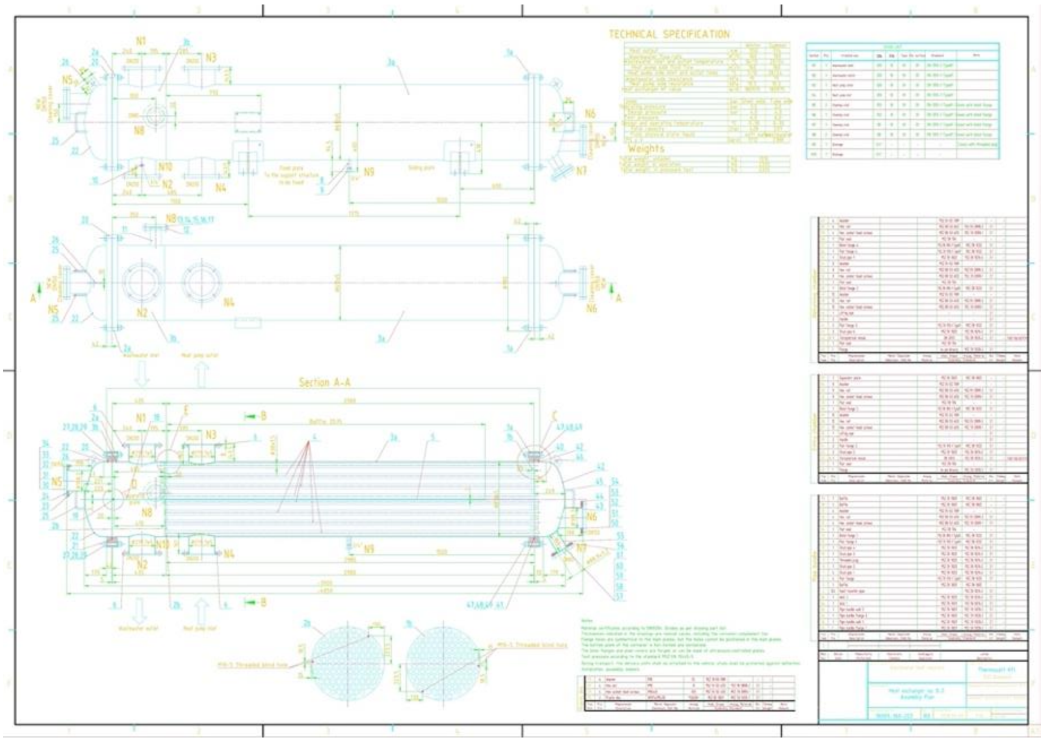

Figure 3. Blueprint of experimental Heat exchanger - B2 type

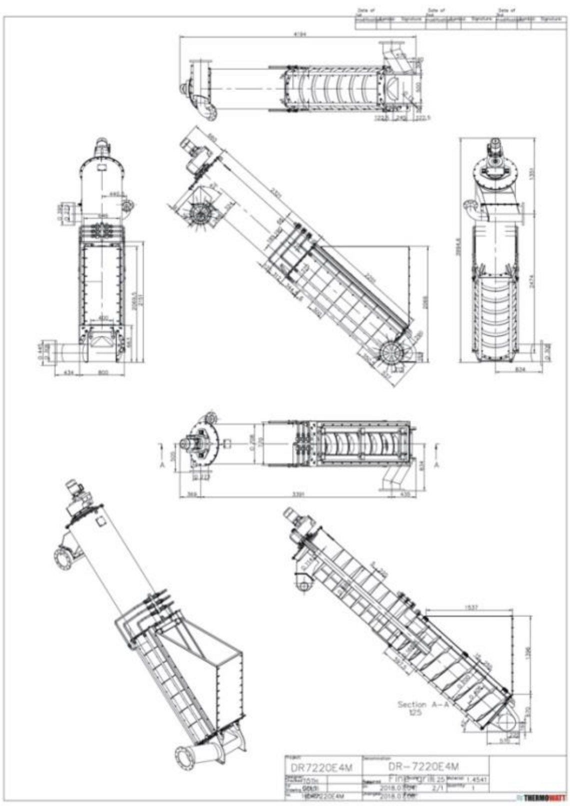

Figure 4. Experimental Fine screen with built-in washer

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2.2 Component Description:

The key element of the wastewater system is the reliable operation of the heat transfer from the wastewater towards the utiliser (mainly heat pumps). In order to maintain the possibility of using the affordable and easy-to-operate, standard serial production heat pumps for our purpose, we have to operate them with an appropriate medium: e.g. clean water. Consequently, a suitable heat exchanger needs to convey the thermal energy from the wastewater to the clean water. Therefore the critical element is the wastewater/clean water heat exchanger, especially on the wastewater side.

Heat exchangers can be ready to receive raw wastewater, but in that case its physical dimensions (and costs) grow extremely. An efficient (and normal size) heat exchanger has relatively narrow channels, where only limited size solid particles can pass through, thus we arrive to the conclusion of wastewater screening being necessary in the equation.

In the confines of the Heat4Cool project extensive R&D was concluded to develop new improved experimental Heat Exchangers and Fine screen along with their cleaning methods. These were then implemented in the Budapest Demo site thus only these parts of the complex Technology solutions will be further detailed here.

Heat Exchanger

One of the most important components of the Thermowatt wastewater solution are the subject-matter tubular heat exchangers.

A heat exchanger is a device which is used to transfer heat energy commonly between two mediums – in the presented case it is between wastewater and clear water. The heat exchange happens through a separating wall (heat transferring surface area) made of a material with a high heat transfer coefficient, usually stainless steel. The separating wall is needed because we do not want the two mediums to touch each other directly, we only need them to exchange their heat energies. It is essential for the system that the two mediums would not be mixed in order to maintain the system's performance without any malfunctions, or operational difficulties.

Thermowatt has decided to develop an innovative shell & tube exchanger, as it turned out to be the best fitting and most efficient base-type to work with an uncommonly used medium: somewhat pre-filtered communal sewage. In tubular heat exchangers the heat transferring surface is the surface of the tube superficies.

One of the most important things is that the wastewater has to be able to circulate without any difficulties, because if any plugging occurs, the whole system might have to be shut down for a cleaning process. Moreover, the heat exchanger efficiency is highly influenced by its contamination. In our case it occurs on the wastewater side and is very much dependent on

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the variety of the wastewater sludge. Therefore, the partners elaborated several conceptual plans for decreasing the clogging and simplifying the cleaning process.

The experimental HEX equipments are horizontal type, two-way tubular heat exchangers with fixed tube bundles, made of stainless steel. The tube bundles are closed by tube bundle walls from the two sides, in which the tube bundles are welded. The sides of the tubes are closed by the container bottom plate on both sides.

2 pieces of device seats are installed in the engine house, with the help of a unique support structure, several heat exchangers can be installed on top of each other, connected in series.

Main specification of the prototypes:

- different inner-tube diameters (35mm, 38mm);
- funnel shaped plates (reducers) with drilled holes (made of Bonobit material) fitted to the entry of the pipes;
- larger drains (DN80);
- wide cleaning and inspection stubs/throats (DN150) on entry sides.

Screening Unit

The purpose of the fine screen is the mechanical filtration of the incoming wastewater in accordance with the desired grade of filtration, on a filtered surface made of perforated sheet metal. It performs the mechanized removal of the filtered screenings discharge from the filter surface, and the cleaning of the latter. It forwards the screenings discharge into the chute with the help of the conveyor screw.

The engineering task of separating the solid particles is very well known in wastewater treatment technology. There is a wide range of machinery available for the so called process of "dewatering". For our purpose the rotary drum/perforated plate fine screen has been selected noting the need for a very important application modification: for obvious operational reasons, the separation of the liquid and solid particles has to be only temporary (since dealing with the separated sludge – which is hazardous waste – being continuously produced in city centre settings of an installation would be difficult) and the separated solid content of the wastewater would be directed into a collector line installed at the original sludge exit point of the screening unit. The screened wastewater is collected in the basin area below the screening unit (in the wastewater shaft) where a submerged pump forwards it to the heat exchangers' wastewater side. After the heat exchange the wastewater is directed to the above mentioned collector line entry, allowing the direct flush back of all separated particles to the main sewer line.

It is very important to know, that the quality of the screening can be detected and evaluated together with the heat exchanger operation, and (except the very bad quality screenings) the period of observation can extend form several weeks to several months. The better the quality of the wastewater filtering is, the longer it takes to have significant and reliable parameter change in the heat exchanger operation.

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Accordingly the prototype screen would serve two tasks:

1. it would be responsible to provide a ‘dirty enough’ wastewater in the appropriate amount and with high reliability for the testing of different cleaning techniques,
2. it would need to be fitted for the final design heat exchangers in order to complement and serve them properly during the experiment and evaluation period of 1 year trial operation – this would provide the time and opportunity to determine the optimal operating strategies.

Main specification of the prototype:

- material: corrosion resistant steel and plastic), filtering capacity: 250 m^3/h
- two special removable perforated filter plates: 4mm and 5mm oval perforated plate for better experimentation on efficiency
- built-in automated cleaning of the screen: 6 tubes with 7 flat fan nozzles each, periodically washes the screen’s back side for better flow rates, higher reliability and filter efficiency

The construction of the fine screen follows the modular principle, with its elements made of corrosion resistant steel. The structure of the machine is a lightweight steel structure. The modular components are bolted to one another or are linked by flexible connections. The installation angle of the fine screen is 42° to the horizontal. The cylindrical, ribbed filter surface is cleaned by helicoid flights whose edge is lined with a brush profile, and the helicoid flights of the neckpiece forward the screen waste to the chute of the machine, from where it is washed back into the effluent branch.
A new system washing the back of the filtering surface has been built in the fine screen. This means to prevent the clogging of the back.Beyond filtering, providing clean enough water (appropriate quality sewage) for the further process, the main requirement of a screen is to insure the necessary flow rate. The cleaning effect of the inside swiping brush to be found in present screening units is not always efficient enough therefore a supplementary solution was sought after: the idea is that an additional, complementary high pressure cleaning could solve the mentioned issue. This direction for achieving a finer filtering for the sake of a more efficient sewage heat utilisation process was a big part of the screening development, given at the Demo 4 site the options for changes were limited by space and circumstances.

HEX cleaning methods

The fouling of the heat exchangers is a very complex physical, chemical and biological phenomenon that is very hard to describe. The obstruction is composed on the one hand of a physical blockage and on the other hand, the formation of a biofilm layer, which, although being parallel processes and therefore possible to separate in a certain context, there are also strong correlations between them. Based on research, it can be said that physical blockage in

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heating and cooling modes cause heat losses of 30% and 27% respectively, i.e. this much less heat can be extracted from the sewage in comparison to the state with clean heat exchangers. Our HEXs efficiency is highly influenced by its contamination. In our case the fouling/clogging occurs on the wastewater's side: at the wastewater inlet and alongside the tube at the same time. The former part of dirt accumulation is concentrated at the tube bundle entry semicircle areas of the sewage line. As the water flow turns before going into the inner pipes, the long fibers stick at the pipes' inlet. Then the constant flow holds these fibers in this fixed position. These become the focus of a physical fouling and over time other little elements are adding to them. As the flow speed slows down more particles get entrapped. Finally, the contribution of the established bacterial colonies, sludge plate is being created. Thanks to the fouling, the mass flow of the wastewater and the efficiency of the heat transport starts decreasing. The other part of the fouling is alongside the tubes. It consists of sedimentation particles and the emerging biofilm.

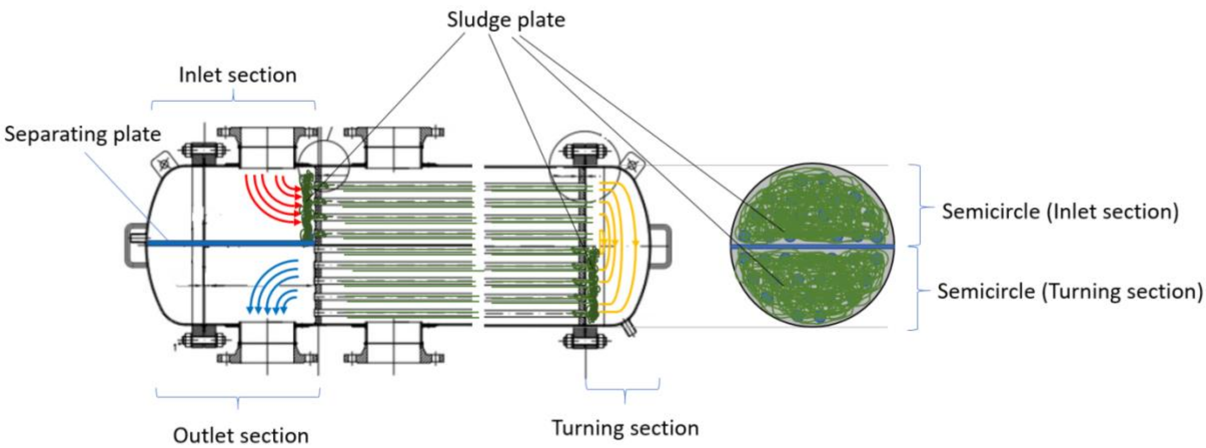

Figure 5. The fouling of Heat exchanger

Cleaning of heat exchangers in the thermal utilisation of sewage is always necessary, as no (economically available) filtration technology exists that would ensure the entry of totally "purified" sewage into the heat exchangers, thereby avoiding contamination. The part of the THERMOWATT technology requiring significant operational and maintenance expenditure and resources is the cleaning (and keeping clean) of the heat exchangers.

Following the conclusions of the R&D and first experimentations there have been 2 chosen cleaning methods included in the implementation (connections) and the HEX designs (special design elements to facilitate the decontamination processes):

1. Counter-current cleaning with wastewater
2. High-pressure cleaning

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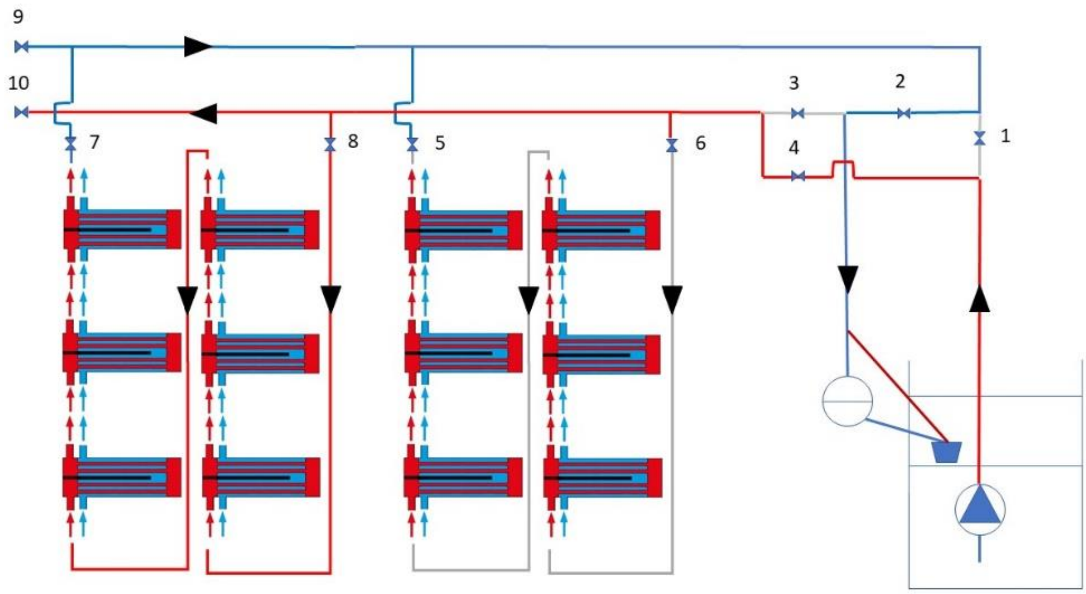

Figure 6. Counter-current cleaning with wastewater

The easiest way to remove contamination could be by counter-current in the wastewater side of a HEX. The hydraulic force which holds the particles in a fixed position would in this case cease and the counter-current would unbundle the sludge plate as the water starts moving to the other direction. Using a higher flow (which means higher hydraulic force) results in more significant effects so the main question for the experimental operating period is how and to what size can we increase the speed of wastewater.

To apply counter-current, we only need to close and open the appropriate valves (provided they have been previously designed and necessary pipe connections are realized). Important advantage of this solution is that there is no need to the drain the water out of the HEX, which makes the cleaning process faster (it will only occur for the purpose of visual confirmation during testing period).

To achieve higher speed of the wastewater, we can **boost the pressure difference.** It is possible to reach two higher levels of speed above the counter-current with the own, built-in pump: we can raise the speed and reach bigger mass flow if one of the HEX groups are disconnected from the others, thus shorter circuit is being cleaned at once.

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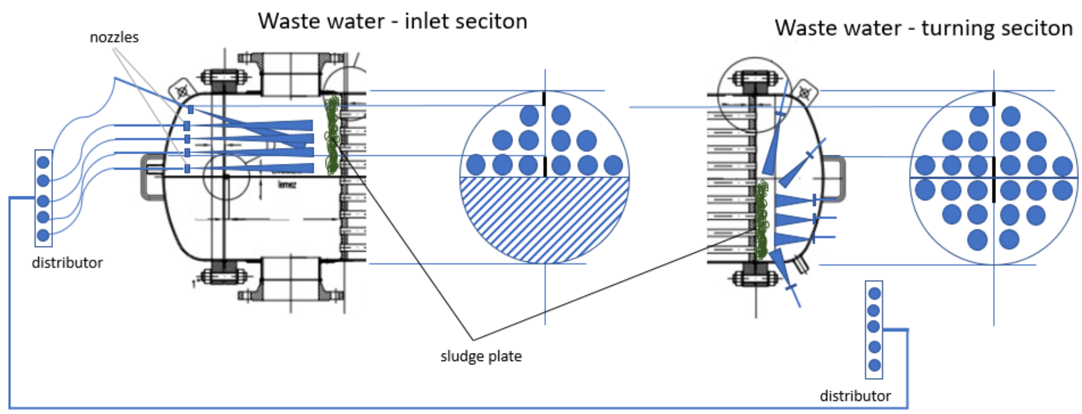

Figure 7. High-pressure cleaning

Other promising solution is the high-pressure cleaning. The concept means that locally applied high-pressure waterjets or air-jet at the inlet semicircle can break off the sludge plate and tear it apart. It has no direct effect on the contamination alongside the tubes.
It is necessary to create certain amount of manifolds on the removable front caps of the HEX units. Then nozzles would be placed in manifolds and the waterjet be lead through these devices (design aspects – relating important considerations are that cleaning stub has to be built differently on the entry side and the reversing chamber and it is worth installing bucket hangers on the front caps).
Given in the case of high pressure cleaning the HEXs are cleaned one by one, the number of HEXs to be cleaned can be reconsidered (in contrast to counter-current). It is supposed that the effect of the cleaning would be almost the same in the case of cleaning only the first two HEXs in comparison with cleaning all of the HEXs (expense optimisation aspect). It is a proposed solution to install the system on the two top heat exchangers and perform relatively frequent cleanings. Included in the Demo implementation all of the new HEXs are fitted for this decontamination method for further experimentation purposes.

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2.3 How It Works:

The temperature of the wastewater is exploited by the help of the heat pump installed in the system construction. This heat can be used for heating or cooling of other locations, according to the current needs. The heat recovery process has no adverse impact on the wastewater composition, thus, the cleaning or bioenergy production parameters will not change after the heat recovery process.

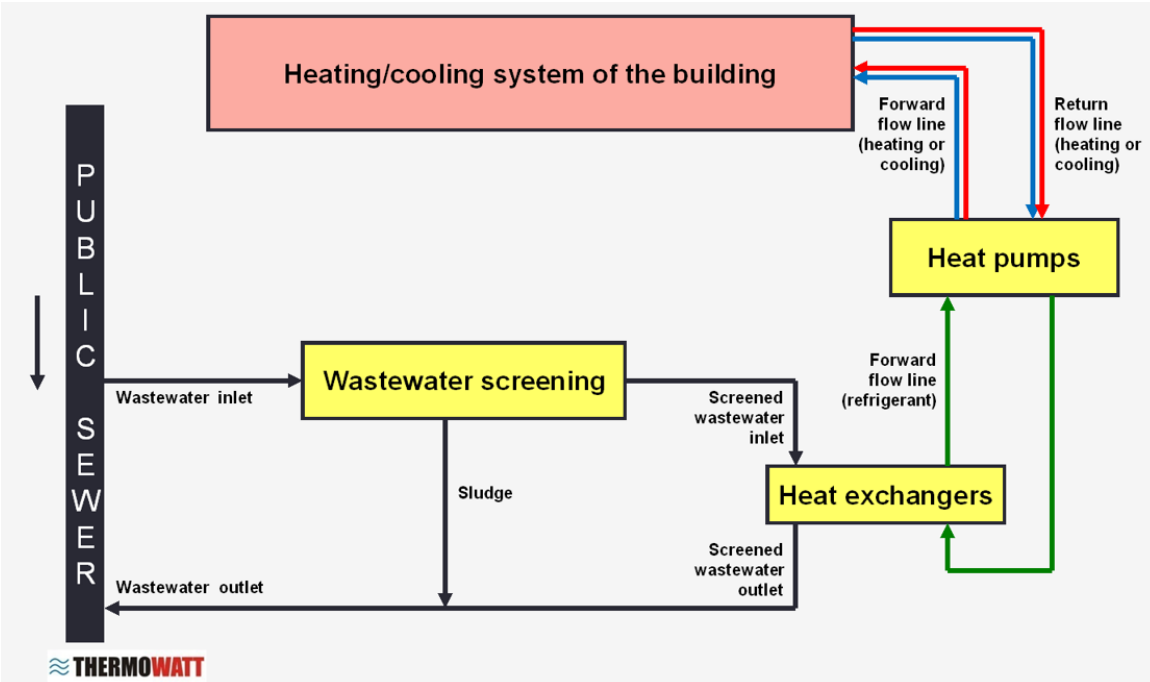

Figure 8. Flows within the Thermowatt system solution

Part of the wastewater is channeled from the main collector to a reinforced concrete chamber (sewage shaft) as part of an engine house. This engine house can be located in- or outside the building above or below the ground. The chamber is a unit separate from the main collector line, but it should be placed as close to it as possible.

The sewage water flowing into the chamber passes through a filter station that removes solid particles from it. Solid particles enter a closed system and are subsequently returned to the main collector line. They are washed back to the sewage network by heat-extracted wastewater returning to the line. As a result, the solid particles of wastewater need to be neither deposited nor transported, while permanent water flow makes the system completely odorless.

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The filtered water enters high-performance heat exchangers. Filtering aims to prevent the blocking of heat exchangers.
Filtered raw wastewater is running through the primary side of the heat exchanger (hereinafter referred to as 'HEX'), while the medium (water, water with glycol, etc.) is running through its secondary side. The heat energy recovered from the wastewater is transferred to the medium of adequate temperature by a water/water heat pump with a compressor unit.
Otherwise, the engine room of the heat pump has the components of a standard engine room.
As performance requirements and average wastewater loads are not the same at all times, a buffer storage tank may be required to manage the differences.
The system is easy to access and easy to maintain which is a key benefit for operators.

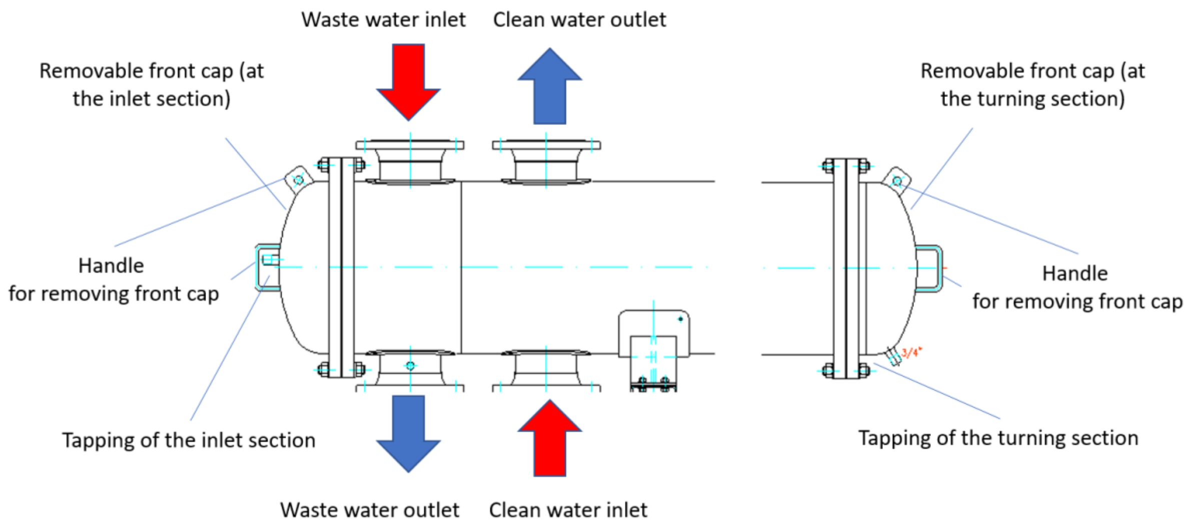

Figure 9. Wastewater – technological water Heat exchanger's waterflow diagram

2.4 Energy and Material Flow

Below diagram introduces the energy balance of the system and the thermal transport processes, the temperature, pressure and volumetric flow rate values and the descriptions of the input quantities of electrical and thermal energy. The explanatory description is built according to the logic of the heating mode. Based on the flowing media, the system can be separated into four circuits.

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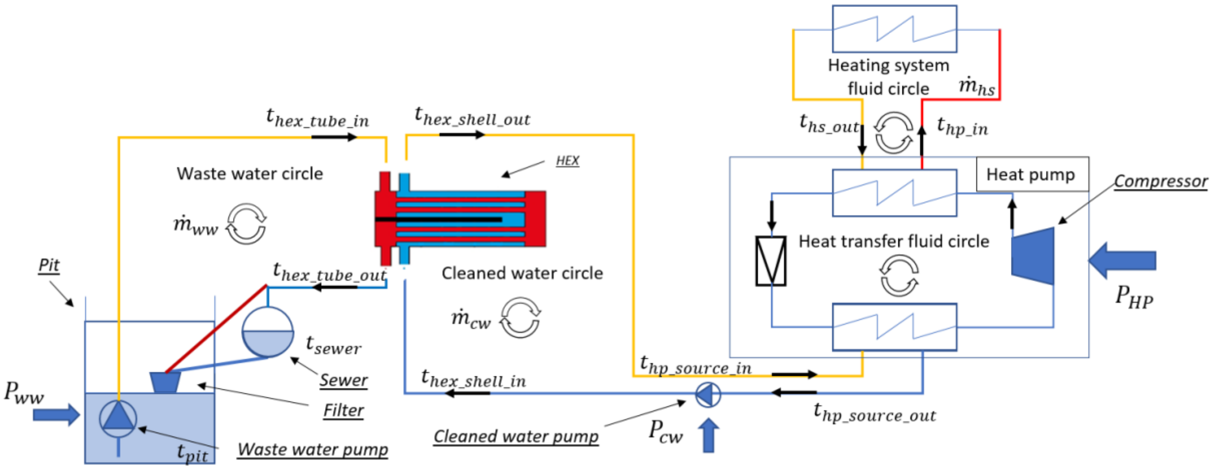

Figure 10. A Connection diagram of the Thermowatt technology (1-4. medium sub-circles)

1. Elements of the Waste water circle (primer medium) - primer side of the HEX

- the primary medium comes from the sewers, entering the shaft through the drum filter, passing through the pipe side of the heat exchanger, finally, dragging the dry matter filtered out by the drum filter, it returns into the sewers again.
- The primary medium is delivered by gravitation into the shaft, from where the sewage pump carries it along the route described above, at its power uptake of (P_{ww}).
- the resultant mass flow rate of the energy input ($\dot{m}_{ww}$)
- the temperature of the sewage in the sewer (t_{sewer}), which is dependent on the season and the current weather (e.g. rain or snowmelt may significantly decrease its value)
- the temperature of the sewage arriving to the shaft (t_{pit}) and the temperature of the filtered sewage forwarded to the heat exchanger line by the pump ($t_{hex\_tube\_in}$) are equal to the value of (t_{sewer}).
- temperature of the sewage exiting the heat exchanger ($t_{hex\_tube\_out}$)
- the heat flow taken from the sewer ($\dot{Q}_{ww}$) – which equals the heat flow taken up by the heat exchanger ($\dot{Q}_{HEX}$) - can be calculated by the following formula, with respect to these:

$$\dot{Q}_{ww} = \dot{m}_{ww} * \Delta t_{hex\_tube} = \dot{m}_{ww} * t_{hex\_tube\_in} - t_{hex\_tube\_out} = \dot{Q}_{HEX}$$

2. Elements of the Cleaned water circle (seconder medium) - secondary side of the HEX

- the secondary medium flows along the shell side of the heat exchanger, and is responsible for the thermal transport between the heat exchanger and the heat pump, therefore it circulates between these two pieces of equipment.
- the mass flow rate of the secondary medium ($\dot{m}_{cw}$) is created by the soft water pump, whose power requirement is (P_{hpw})
- temperature of medium entering the shell side ($t_{hex\_shell\_in}$)

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→ this equals the exit temperature on the source side of the heat exchanger ($t_{hp\_source\_out}$)

- temperature of medium exiting the shell side ($t_{hex\_shell\_out}$)

  → this equals the entry temperature on the source side of the heat exchanger ($t_{hp\_source\_in}$)

- the heat flow taken by the secondary medium ($\dot{Q}_{HEX}$) - which equals the heat flow forwarded to the heat pump - can be calculated by the following formula:

$$\dot{Q}_{hp\_source} = \dot{m}_{cw} * \Delta t_{source} = \dot{m}_{cw} * t_{hp\_source\_in} - t_{hp\_source\_out} = \dot{Q}_{HEX}$$

3. **Elements of the Heat transfer fluid circle (tercier medium) – source side of the heat pump**

- The heat transfer fluid will undergo a change of state of matter, while it will absorb the heat by evaporation on the source side and discharge it by condensation on the discharge side.
- To implement the process, electrical power input is required (P_{hp}).
- The heat forwarded by the heat pump to the heating system is given by the sum of the heat taken up by the heat exchanger and the electrical power input:

$$\dot{Q}_{hp\_output} = \dot{Q}_{hp\_source} + P_{hp} = \dot{Q}_{HEX} + P_{hp}$$

4. **Elements of the Heating system fluid circle (4th medium) – output side of the heat pump**

- The fourth circuit is the fluid circulating in the heating/cooling system
- The mass flow rate of the 4th medium ($\dot{m}_{hs}$) is created by the heating/cooling network circulator pump, as a result of electrical power input (P_{hs}).
- The temperature of the input fluid of the system is (t_{hs_in}), and that of the return fluid is (t_{hs_out})
- The inlet heating capacity of the heating/cooling system - which is equal to the heat capacity dissipated by the heat pump - can be calculated by the following formula.

$$\dot{Q}_{hs} = \dot{m}_{hs} * \Delta t_{hs} = \dot{m}_{hs} * t_{hs\_in} - t_{hs\_out} = \dot{Q}_{hp\_output}$$

- A condition stated as a requirement for the technology is the temperature required by the consumer in heating or cooling mode (t_{hs_in}) or what temperature must be produced with the heat pump (t_{hs_out}).

The efficiency of the heat pump is the quotient of the effective thermal power and the electric power consumption: in heating mode the values of COP (C.O.P, Coefficient Of Performance) and EER (E.E.R. Energy Efficiency Ratio) are used to express it in heating and cooling mode respectively. In case of heating, the useful heat is generated on the condenser side, while heat is dissipated into the heating system's 4th circuit's inlet side, and in case of cooling, it removes the heat of evaporation.

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$$COP_{hp} = \frac{\dot{Q}_{hp\_outpt}}{P_{hp}} = \frac{\dot{Q}_{condenser}}{P_{hp}}$$

$$EER_{hp} = \frac{\dot{Q}_{hp\_outpt}}{P_{hp}} = \frac{\dot{Q}_{evaporator}}{P_{hp}}$$

The COP and EER values of the entire system (technology) are lower than the efficiency values of the heat pump, because it has to include the power consumption of the other technological auxiliary equipment, such as the sewage pump and the soft water pump besides the heat pump.

2.5 Performances

Even though consumer demand follows a daily pattern, but only minor deviations occur in these in comparison to the annual pattern. As the technology is typically aimed at supplying the heating and cooling demands of buildings, consumption is adjusted to the external temperature, i.e. consumption is higher during more pronounced winter cold and summer heat. The temperature of the sewage is slight dependent on outdoor temperature; thus it will be coldest during winter and warmest during summer (however its temperature fluctuation is far from that of other possible heat sources like air, natural water, ground water, …). The COP of the heat pump depends on the temperature received from the equipment ($t_{hp\_source\_in} = t_{hex\_shell\_out}$) and the current load state ($\dot{Q}_{hs}$).

In the transitional period smaller demands are present and sewage of more favorable temperature is available.

The COP (coefficient of performance) of the heat pump depends on the temperature received from the equipment ($t_{hp\_source\_in} = t_{hex\_shell\_out}$) and the current load state ($\dot{Q}_{hs}$).

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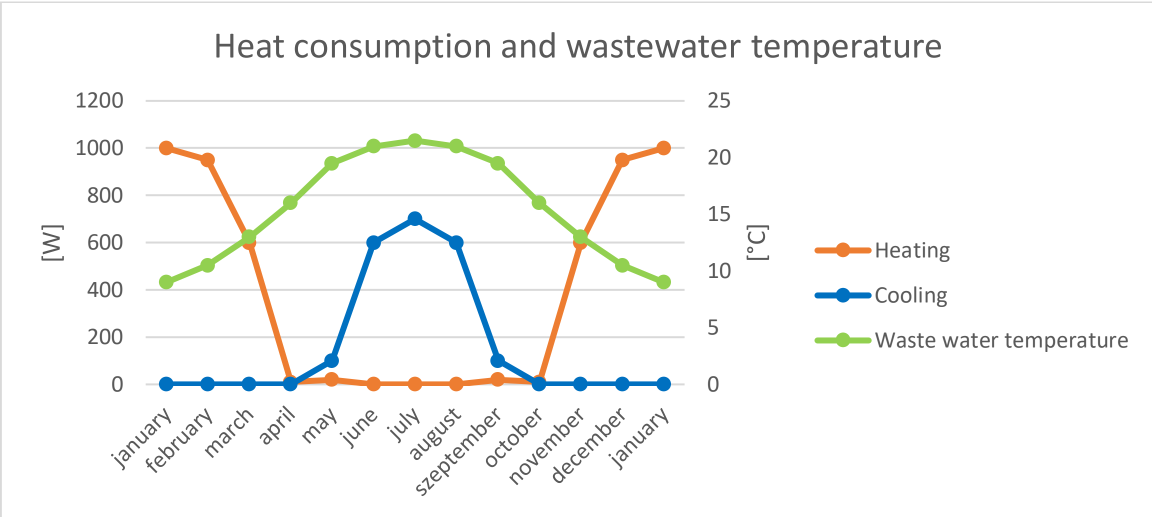

Figure 11. Heat consumption and wastewater temperatures

System size and performance numbers

With the Thermowatt wastewater utilizing solution heating and cooling thermal supply is produced via the same system construction. The base system implemented at the Budapest site can be characterized with the following technical details:

Flow of wastewater (# of HEX: 12):	250 m3/h
Average temperature of wastewater:	17°C
T of return wastewater (heating):	10°C
T of return wastewater (cooling):	25°C
Heat Pump capacity in heating mode :	981+709=1690 kW
Heat Pump capacity in cooling mode :	1020+728=1748 kW
Efficiency (HP):	**COP/EER: 3.85/5.8**
Δ T (heating) :	60/50 °C
Δ T (cooling) :	7/12 °C
Flow of water (heating):	212 m3/h
Flow of water (cooling):	302 m3/h

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Power demand (above heat pump): 42 kW

The new heat exchanger elements can take over ~ 30% of the whole system capacity (~150kW / HEX unit). The new fine screen's capacity is 250 m3/h.

3 TEHNOLOGY SOLUTION ON SITE – demo site in BUDAPEST

3.1 Demo site presentation:

The pilot site in Hungary is located in Budapest, in District 4 - Újpest at the St. Stephan Square.

Figure 12. Aerial overview of the district system demonstration site in Budpaest

The pilot site in Hungary will be the example for district system installation thus it consist of 3 different buildings being serviced from one heating/cooling centre in a district like supply

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structure. At this demo site the focus is on the thermal supply for district structure, evaluation of sufficiant technologies for the task and bettering thermal supply efficiency.
At the site there is a wastewater heat (WWH) recovery system installed (size 1.7 MW) and it provides the opportunity of installation and evaluation (efficiency monitoring) of the new innovative WW HEX system which would become part of the district heating and cooling supply – taking over approximately 1/3 of the present capacity (total capacity 500-750 kW).
In the district supply circuit there are 2 already existing buildings (to be retrofitted) and 1 newly constructed building (still under construction) included.

The total affected area is 12 500 m^2:

- Mayor’s Office: ~2600 m^2
- Government Window: ~1900 m^2
- New Market Hall (under construction construction): ~8000 m^2

The 2 buildings to be retrofitted are public – municipal administration buildings, that means the buildings consist of mainly offices, meeting and conference rooms.

Figure 13, Introduction of the 3 supplied buildings and their location at the Budapest Demo site

Location of the system

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The construction site is located in Budapest, in the 4th district, at Saint Stephen square. Initially it was an overground parking area for cars. The sewer is situated next to the parking area underneath the road bounding the square.

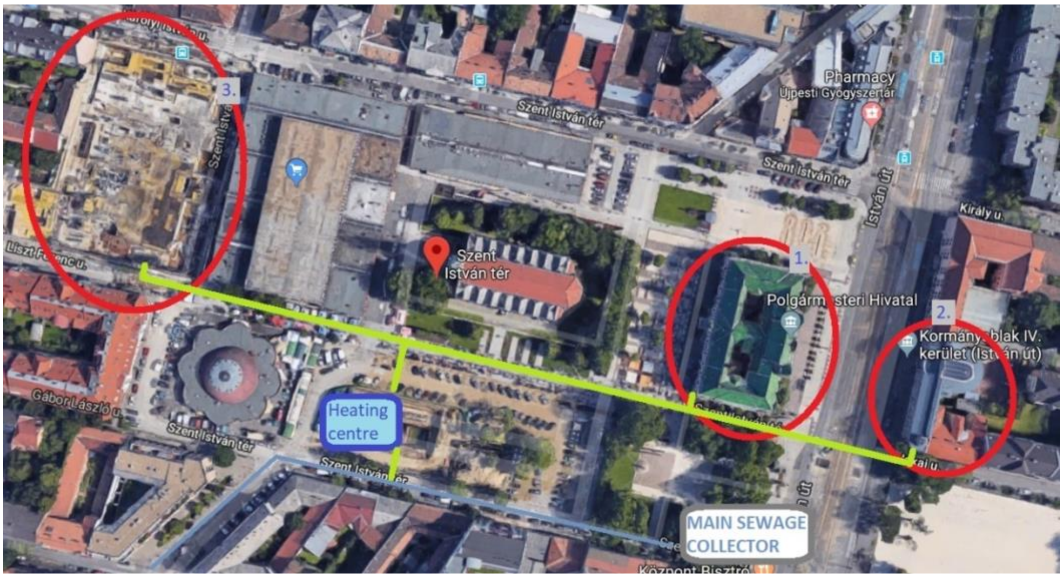

Figure 14, Location of the construction site, the underground heatning centre and the main sewage collector

The sewage heat utilising system's underground engine house is built underneath an overground parking area and is joined to the sewage network's main collector pipeline situated only 5.7 m away. The two pairs of the outgoing pipes from the Northern side of the station are heading towards the buildings which will be heated or cooled by the system: the 2 lines on the left are heading to the newly constructed market hall and the another pair of pipelines are approaching the other two buildings (Mayor's Office and Government Window).

At the Budapest Demo site that is the district example in the project only the wastewater heat utilization is concerned. (No SCI-BEMS either)
The prototypes of the wastewater heat utilising system elements developed during the Heat4Cool project – HEXs and fine screen – along with necessary accompanying equipment, piping, the device requirement of selected cleaning methods were placed by the side of the base system in the underground engine house at St. Stephan Sq, Budapest, District 4.

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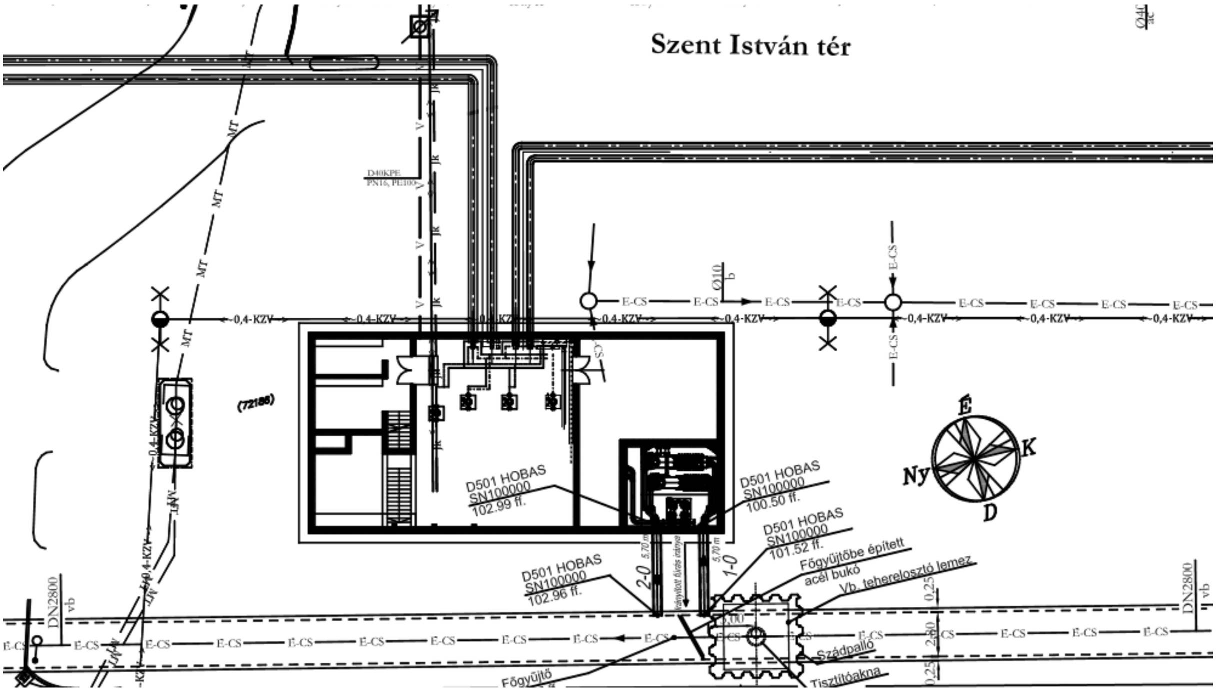

Figure 15. The sewage main collector and the Thermowatt system's coonnection

The available sewage network

The most relevant sewer is located on the Southern part of Saint Stephen square, which is a combined system pipeline, which means that the rain-water and the wastewater from the nearby buildings are being collected together in this channel. The dimension of the ferroconcrete sewer is DN2800 mm.

In our case this main collector is the only supplier of the wastewater for the system. The minimum volume flow of the wastewater, which has been measured, was around 500 m^3/h. The average yearly temperature of the wastewater is around 17.2-17.8 °C (average temperature of the wastewater in summer is around 20-22 °C; in winter 14.5-15°C), which is a very great basis for utilization in a heat pump based heating system. In total the average volume of wastewater in the main drainage channel, from which we are able to recover the heat energy, has been between 18,000-20,000 m^3 daily.

As the calculations were made, a minimum of 500 m^3/h (12,000 m^3/h) wastewater flow could perfectly satisfy a system with 3.0-3.7 MW heat capacity, without utilising any buffer tanks or storage. This means that there is plenty of available sewage in the subject collector and thus it would be possible to satisfy the energy need of many surrounding buildings by installing and maintaining such a system.

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3.2 Installation

The main items of the installation were the following:

- 2 x 2 different design HEXs → will take over 30% of current capacity (~600kW)
- 1 Fine Screen (+ww pump, water tank for automated washer)
- meters, sensors, ..
- necessary piping, valves, …
- SCADA expansion

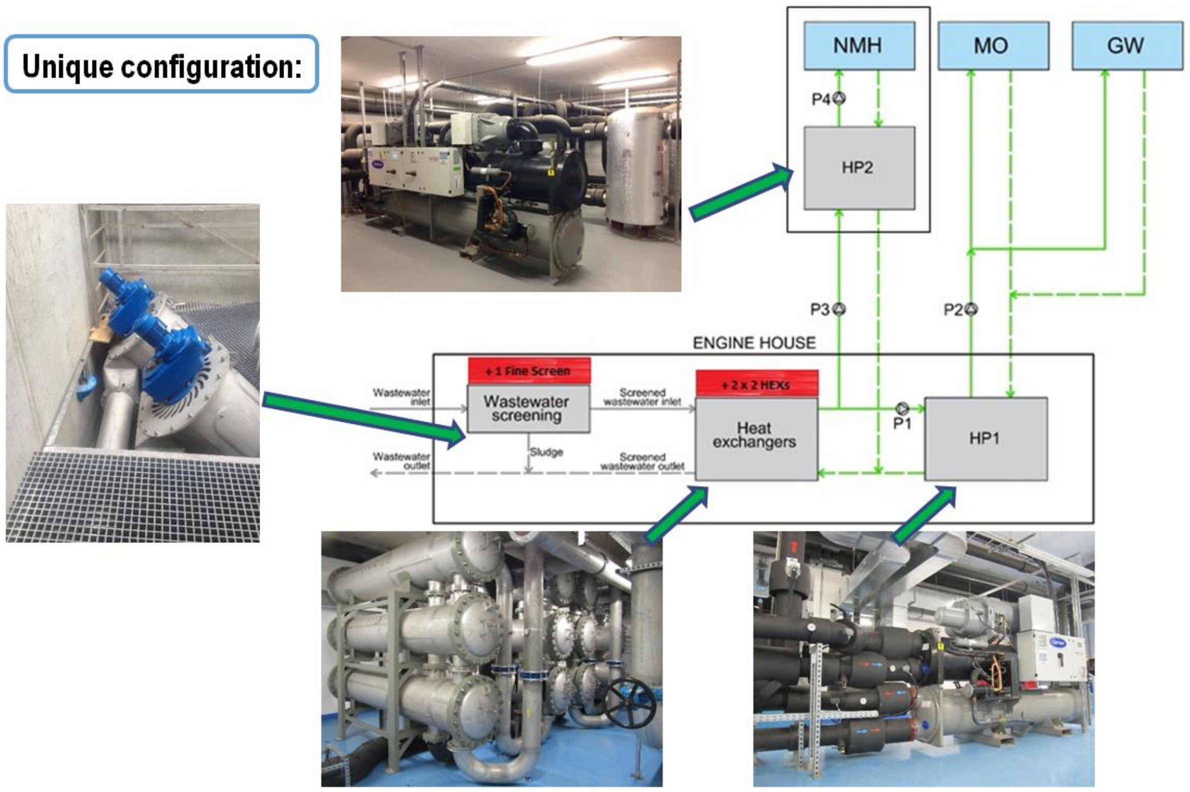

Figure 16. Main Items of the installation and their position within the system structure

Overview scheme of the Budapest Demo site

During the elaboration of the installation plans and designs limited space availability in the underground engine house had to be accounted for.

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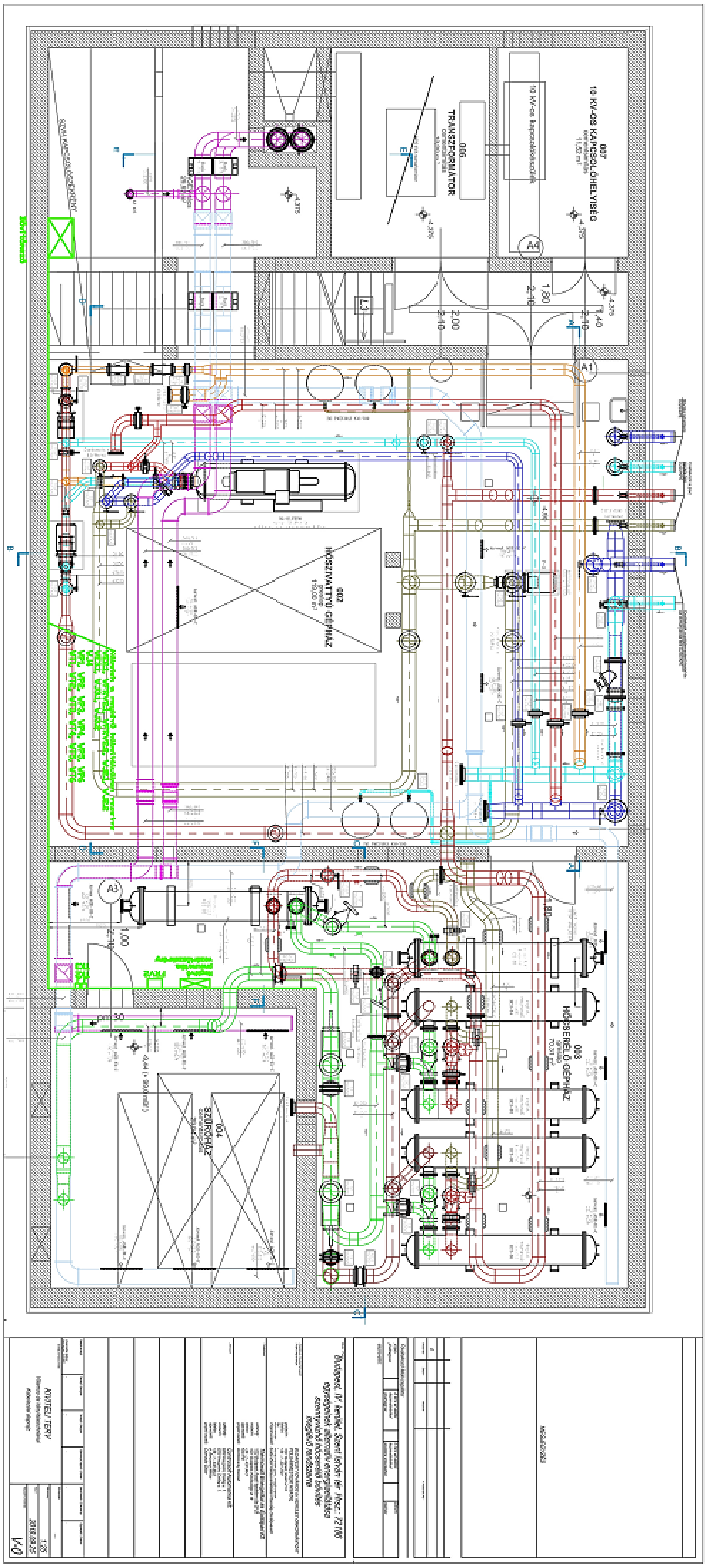

Figure 17. Budapest Demo site: installation design – connection to the base system

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The following specifications were included or had to be taken into account for the finalisation of the installation's engineering plans:

HEX room engineering plans

- 2xA2, 2xB2 HEXs
- Connections (wastewater, clear water) – DN200
- Joint connection with Sewage shaft
- New HEXs can be completely separated (with SV DN200 gate valves) → different configurations and operation protocols can be tested and analysed
- 6 (2x3 in series) – 6 (2x3 in series) – 4 (2x2 in series) in parallel
- Possibility of counter-current connection is included in the structure

Sewage shaft engineering plans:

- Implementation of 1 Fine Screen, 1 wastewater pump (Grundfos SL1)
- Capacity: 250 m3/h, grade of filtration: 4mm
- Connecting to the existing incoming sewage inlet pipe's reducer profile (DN300); mechanical and pneumatic gate valves
- Variable/detachable perforated plate options: 4mm round + 5mm oval → different configurations and operation protocols can be tested and examined (past and new screen can be mix-and-matched); *brush wear/ screen work/electricity consumption/cleaning frequency vs efficiency increase*
- Built-in washing system at the filter surface (placed to avoid clogging): 6 tubes, 7 flat fan nozzles each, periodically washes (high pres.5-7 bar, 4m3/h, 2m3 tank) → *testing efficiency/increasing brush's life expectancy/increasing flow vs electricity & water consumption*
- Clear water tank to supply screen washer, connection pipes
- DN125 (utilised wastewater inlet), DN250 (re-mixed effluent outlet)
- Fine Screen maintenance platform – foldable stairs

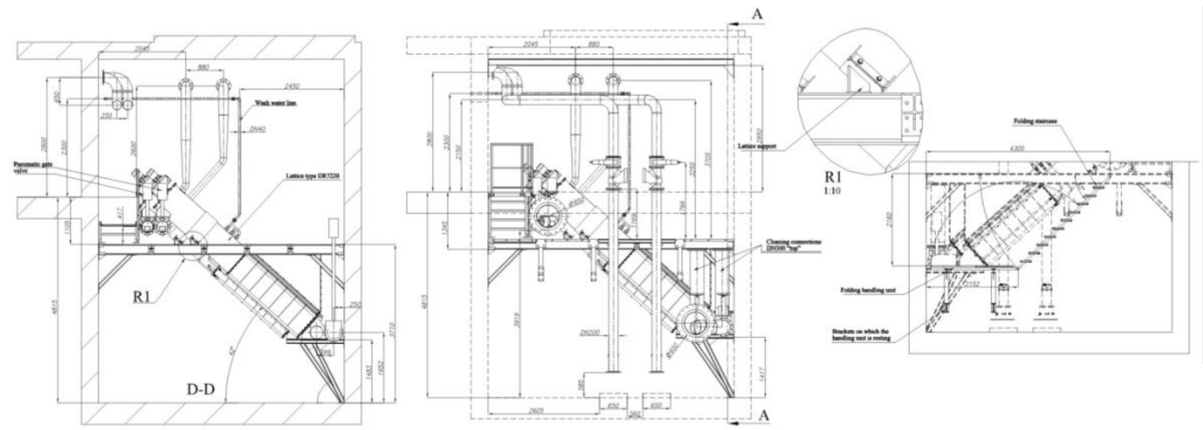

Figure 18. Budapest Demo site: installation design sewage shaft chamber

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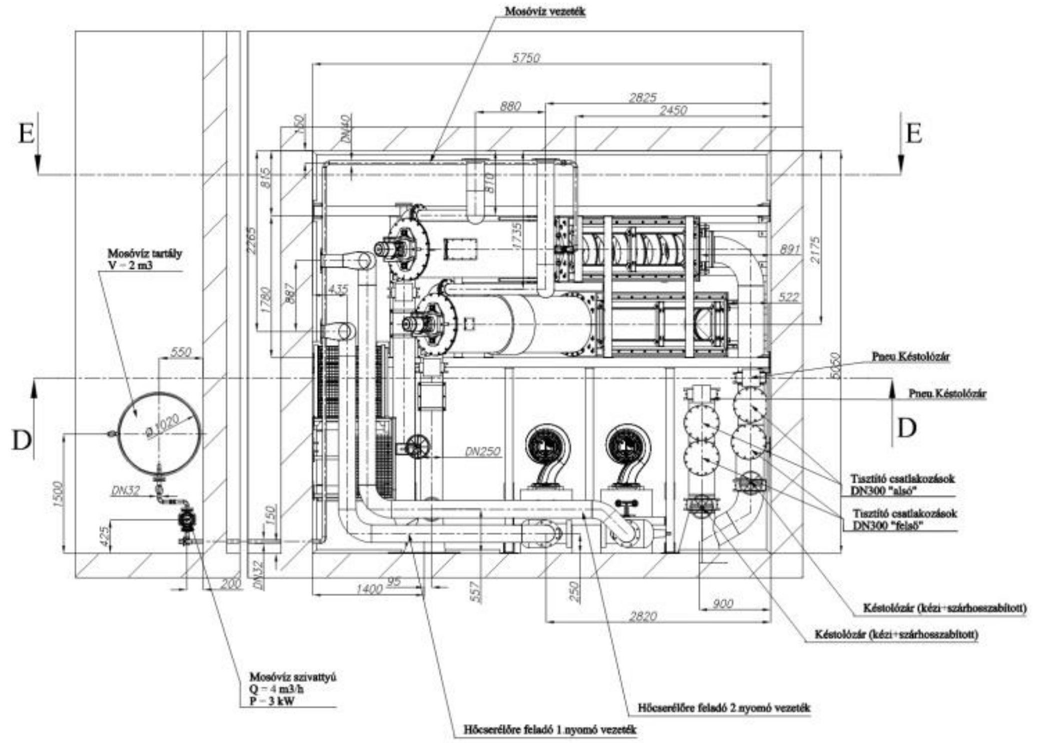

Figure 19. Budapest Demo site: installation design sewage shaft chamber and placement of the water tank for the Fine Screen's washer

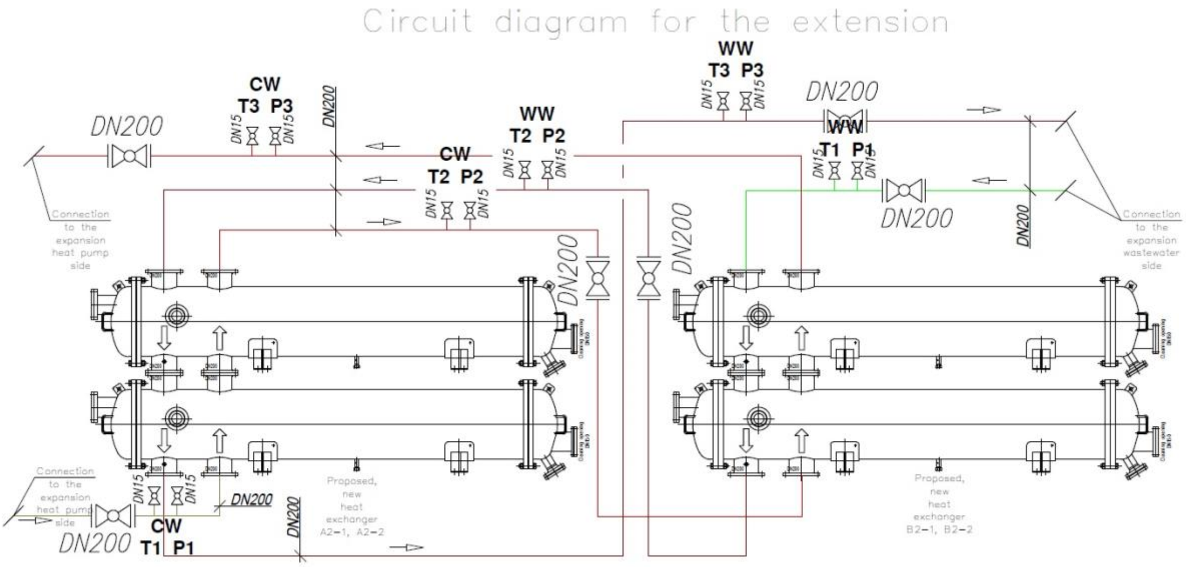

Figure 20. Monitoring positions in the system

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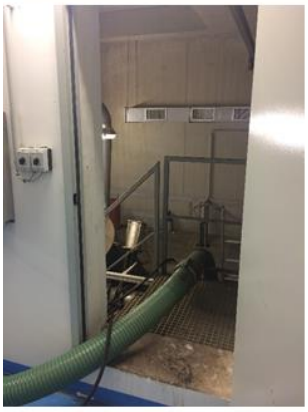
PICTURE GALLERY – BUDAPEST DEMO SITE INSTALLATION

Site preparatory works & parking place demolition:




Sewage shaft draining & cleaning:



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Ceiling lifting






HEX transportation & placement






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Fine screen transportation & placement

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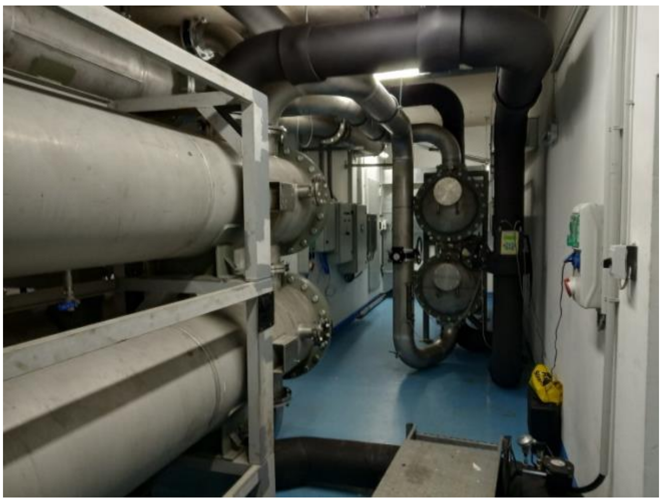
Demo Site after Installation – Wastewater Shaft Equipment




Demo Site after Installation – Heat Exchangers

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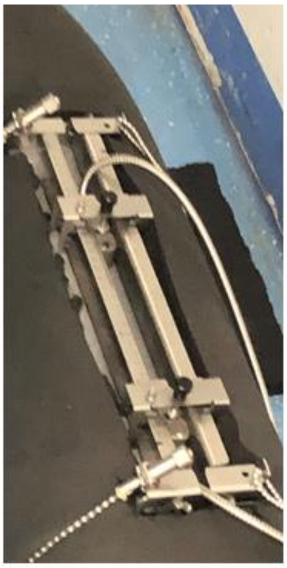
Demo Site after Installation – Control Elements

Demo Site after Installation – Monitoring Supplement



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Demo Site after Installation – Screen Washing Water Supply

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3.3 Demonstration of the benefits in the real case and how the different technologies are integrated

In the Budapest demo site there is the demonstration of only a wastewater heat recovery, allowed by experimental innovative heat exchangers.

Moreover, the Budapest demo site is connected within the local district system, supplying 3 different buildings, counting all altogether ~12.500 m2 of surface area serviced.

Benefits provided by this system construction, demo implementation:

- ✓ no necessity of the implementation of separate heating and cooling solutions in the buildings connected to the district network
- ✓ the same system is used for both heating and cooling supply, which is space and cost effective especially in larger networks like in the case of the Demo site
- ✓ simultaneous heating and cooling supply is possible, completely green and renewable, with the elimination of fossil energy sources
- ✓ through a collective impact of the new HEXs, the new cleaning methods as well as the developed fine screen higher efficiency and operation safety levels are achievable.

The system in Újpest grants thermal energy for two buildings from the initial thermal center, and for the third one through another separate heat pump station, with the possibility to install more heat pump stations in order to expand the whole system.
In the whole network there is only one thermal center, which contains every part of our system: the wastewater collecting well, the filtration, the heat exchangers and the heat pumps. This main engine house's task is to recover the heat energy from the wastewater through the heat exchangers. There are two main reasons why we do not support the installation of more thermal centers with all of these equipment in the area.
The first one is in connection with the financial side, installing more systems with every parts, are much more expensive than making the distribution by pipelines. Every fully equipped system's installation requires relatively close distance to sewers with enough wastewater flow, also every system needs its own filtration system and heat exchangers as well, not only the heat pumps. It can be seen that it is much more complicated to install several whole functioning systems in the area, and also it is more expensive than installing only one heating central with several heat pump stations in a distributed way.
The second reason is in connection with the transportation of the wastewater. If we cannot find sewers with enough mass flow of wastewater in a close distance, then through the transportation there would be more losses of heat energy. To by-pass this disadvantage, we are transporting not the wastewater but the technical clean water of the heat exchangers' opposite side to the heat pump stations. With this solution we can lower the heat loss of the total system compared to the wastewater transportation as well as simplify the distance pipeline system to be constructed.

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In the future we would like to settle more heat pump stations, in order to widen the district thermal supply network in the area and to become an even wider district heating system. These individual heat pump stations would make it possible to adjust the required water temperature for every building's own requirements, so they would not be forced to use other temperature water than what is necessary. This idea opens up several more potential solutions. For example utilising smaller heat pumps, with around 10 kW capacity, which can make the system suitable for not only larger buildings' heating and cooling systems, but also for individual households as well.

Objectives of monitoring and evaluation:

- Objectives: observation, assessment and analysis of the performance of all three elements – new HEXs, new cleaning methods and the new screen –, overall performance and savings achieved by the complete system
- Opportunity to further test several different operation protocols and settings, mixing connections between the old and new elements, simulate different supply and service demand, situations, circumstances, in favour of painting a complete picture about the behaviour and performance of the recently developed system elements.
- Monitoring and logging the performance, operation, efficiency, supply and consumption data of the main system elements as well as of the complete system is essential → implementation of necessary meters and sensors, SCADA expansion will be carried out.
- Evaluation of the developments will be undertaken as the trial period finished and data is processed

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